Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

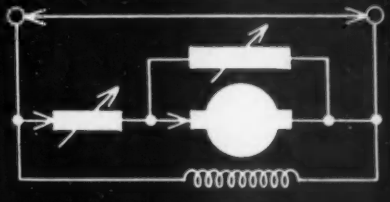
A McGraw-Hill Publication

75 Cents

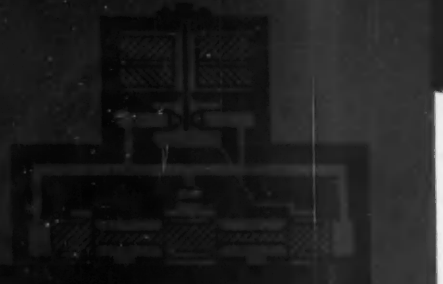
JUNE 1960

Statistics from High Speed Analogs

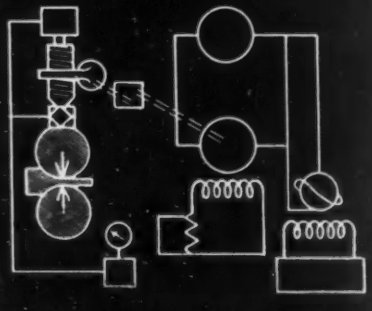
European Electronic Process Control Systems



Speed Control Methods for Dc Motors



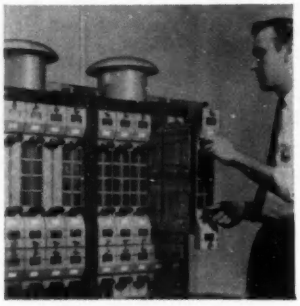
Don't Overlook the Switching Valve



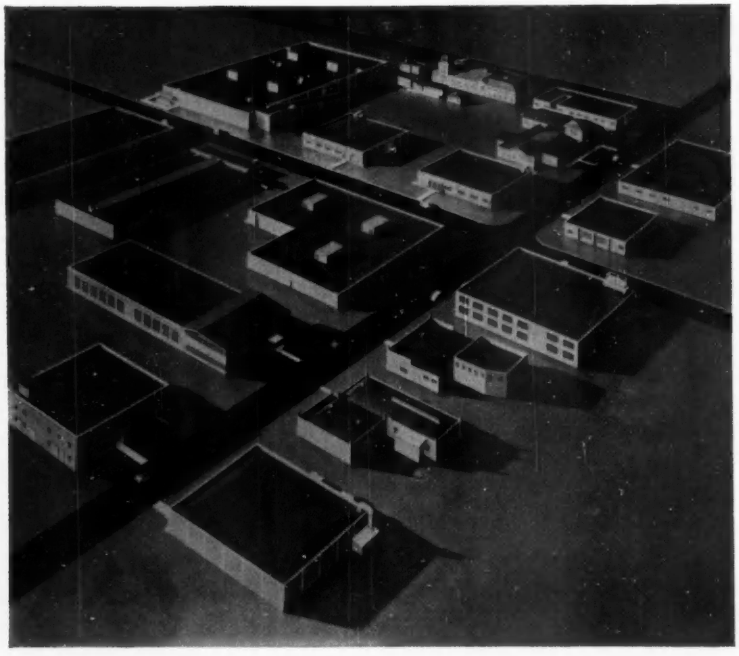
Controller Studies on Small Scale Mills

LIBRASCOPE COMPUTER FACILITIES

Shown below is a composite view of Librascope's facilities where a variety of computer systems are currently in different stages of design and production. Some are strategically involved with national defense...others deal with business and industrial process control. Each is uniquely designed to answer a particular need. The success of these systems illustrates the value of Librascope's engineering philosophy: A decentralized organization of specialized project teams responsible for assignments from concept to delivery...and backed up by excellent research, service, and production facilities. For your computer requirements, call on the company whose breadth of diversification in computer technology is unsurpassed. ■ Librascope Division, General Precision, Inc., 808 Western Avenue, Glendale, Calif. For career opportunities write to John Schmidt, Engineering Employment. ■



computers that pace man's expanding mind



CIRCLE 205 ON READER SERVICE CARD

In operation since February, the L&N computer gives Carolina Power & Light Co., the desired generation loading pattern on five of its major plants for strict incremental loading, or modified economy loading. The computer can also be used to study anticipated operating problems and their effects on the cost of operating the system while the load control is still functioning.

Carolina Power & Light Co. closes the control loop with new L&N dispatch computer

New L&N "Desired-Generation" Computers Now Operating On Six Major Power Networks

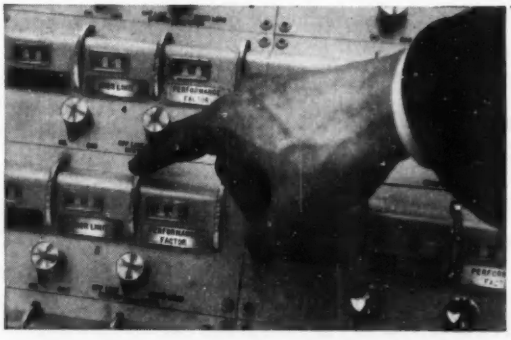
Like so many utilities, CP&L's steep growth curve of the past ten years is exceeded only by expansion estimates for the next ten. To ensure that system operation remains economical and smooth during rapid expansion, CP&L now uses an L&N Desired-Generation Computer-Control system for automatic control of better than 90 per cent of generation on its major (eastern) operating area. The new control encompasses telemetered values from five tie points and automatic allocation of generation changes among five major generating stations, including 14 units under control.

In moving ahead with an L&N system, CP&L is part of a growing trend, for within a year after installation of the first Desired-Generation Computer, six major American utility networks with a combined capability of 11 million Kw were using L&N computer-controllers.

Suggestion: you can help *your* system make the move to advanced automatic dispatching more objectively — and with confidence — by checking *results* first — the actual operating results being obtained right now from California to Carolina, from Connecticut to Florida (names on request). Then, talk with the men of Leeds & Northrup—or write to 4918 Stenton Avenue, Phila. 44, Pa., about a custom-engineered computer-control for your system—it pays.

Get results on your system with an L&N computer that:

1. *Automatically loads generating units on an incremental cost-of-power-delivered basis—includes incremental generating costs and transmission loss factors (transmission loss matrix optional).*
2. *Provides real operating flexibility: loads on any desired incremental, or modified economy basis, to meet prevailing system conditions.*
3. *Plots "on-the-spot" graphic answers to problems involving economy interchange, power-flow losses or anticipated loading patterns.*
4. *Derives a measured lambda value —incremental cost of power delivered—at all times.*
5. *Invariably adjusts generation in a direction that reduces area requirement.*
6. *Gives each unit a terminal destination.*
7. *Makes it easy to place units on control—just flip a switch—no synchronization required.*
8. *Provides safety margins: adjustable load limit settings are positive, and cannot be exceeded; maximum rates of control action are positive, adjustable, and cannot be overridden.*
9. *Costs less in the long run: requires no unit or governor modifications, goes into service after approximately two to four weeks installation procedure, gives positive assurance against overregulation.*
10. *Is easy to operate—gives any desired readout data, uses compact, convenient digital setters.*



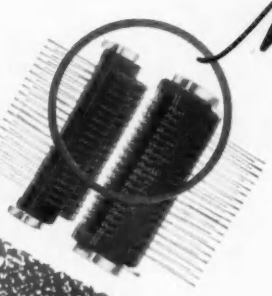
Digital setters are just one of many operating aids built into L&N computers. Compact and easy to use, these setters enable you accurately to feed into the computer a wide range of input data: unit high and low limits, performance factor, type and cost of fuel being used, etc.

LEEDS LN **NORTHRUP**
"Over 400 automatic generation control installations"

Micro Min / 1 5/16" long

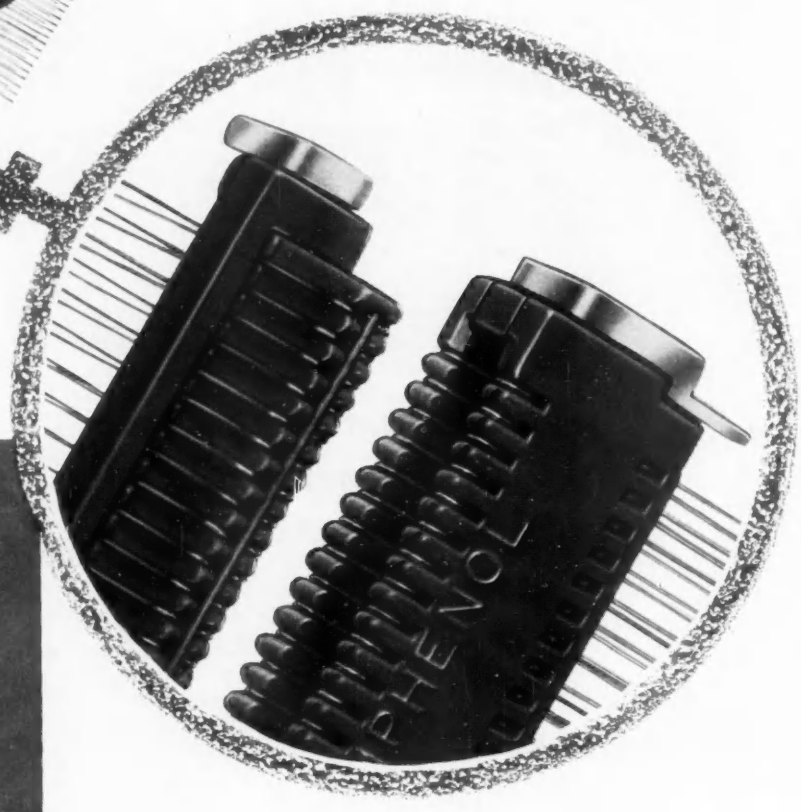
with 38 contacts on .050" centers

38 CONTACTS
DOUBLE SIDE



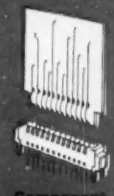
actual size

19 CONTACTS,
SINGLE SIDE

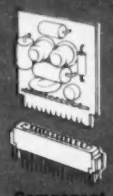


SUGGESTED APPLICATIONS

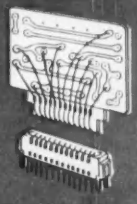
19 Contacts, Single Side



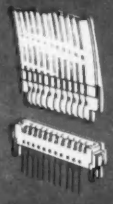
Component Mounting Board and Receptacle (front view)



Component Mounting Board and Receptacle (back view)

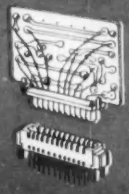


Printed Wiring Board Adapter, and Receptacle

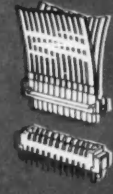


Flexible Printed Wire Cable Plug, and Receptacle

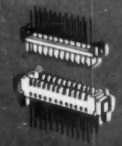
38 Contacts, Double Side



Printed Wiring Board Adapter, and Receptacle



2 Flexible Printed Wire Cables with Adapter, and Receptacle



Plug and Receptacle for Module/Chassis/ Cable Applications

These are the **FIRST MICRO MINIATURE** *connectors!*

AMPHENOL's new ***Micro Min*** *100 Series* connectors for micro-miniature circuitry are the smallest connectors ever developed. AMPHENOL engineers have achieved a startling 50% size, 80% weight reduction from standard miniature connectors; full-size reliability has been built into connectors only 1 5/16" long and 1/4" wide, weighing only .008 lbs. a pair! And, most remarkable of all, ***Micro Min*** *100's* low capacitance contacts are centered on .050", with .040" spacing between contacts!

Handling and assembly are surprisingly easy in connectors so small. The heat-treated beryllium copper contacts may be terminated by soldering or welding with little or no more difficulty than standard miniatures.

Micro Min *100 Series* are now in production and are available for your evaluation. See or call your AMPHENOL Sales/Engineering Representative!

CIRCLE 2 ON READER SERVICE CARD

AMPHENOL **CONNECTOR DIVISION**
1830 SOUTH 54TH AVENUE, CHICAGO 50, ILL.

Amphenol-Borg Electronics Corporation

Control ENGINEERING

JUNE 1960

VOL. 7 NO. 6

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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95 **Investigating Thickness Control on Small Scale Rolling Mills**
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---

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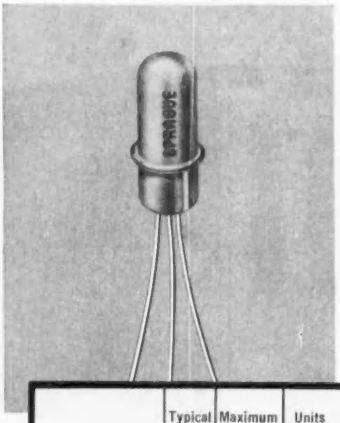
22

Type 2N501 Super High-Speed Micro-Alloy Diffused-Base Transistors

(2 X Actual Size)



	Typical	Maximum	Units
Rise Time (t_r)	9	18	mμsec
Storage Time (t_s)	9	12	mμsec
Fall Time (t_f)	7	10	mμsec

In circuit with current gain of 10 and voltage turn off.

Unexcelled for super high-speed computer applications, Sprague's Type 2N501 Micro-Alloy Transistors combine high gain and high frequency response with unusual stability and high operation efficiency even under severe environmental conditions and life tests.

Sprague's mechanized electrochemical process permits the fabrication of a graded base transistor with no intrinsic base region. The Type 2N501 can thus maintain its super high-speed switching characteristics right down to its saturation voltage, providing all the advantages of direct-coupled circuitry with no impairment of switching speeds.

Write for complete engineering data to Technical Literature Section, Sprague Electric Company, 407 Marshall Street, North Adams, Mass.

SHOPTALK

More service to the readers

With this issue the reader service functions of CONTROL ENGINEERING have at the same time been both expanded and consolidated in one place to make the magazine more useful to our subscribers. From now on all of the items that call for reader communication will be contained in a four-page Reader Service Dept. (see p. 169). Things to note are:

1. Major addition is complete index by type of equipment of all advertisements, new products, and catalogs and bulletins. Classified under functional headings such as systems, data handling and display equipment, transducers, etc., the reader can immediately find out whether any new devices of the type he's particularly interested in at the time are covered in the issue. Additional information can be obtained by circling the number on the reader service card corresponding to the number preceding the indexed item.
2. The reprint order coupon has been dispensed with: to order reprints in the future, circle the number on the reader service card corresponding to the number listed on the last page of the Reader Service Dept. Detailed descriptions of all the reprints are still given (see p. 196).
3. Choice features from the forthcoming issue will be described on the first page of the department.
4. Subscription card permits you to subscribe easily.

Boy were they good!

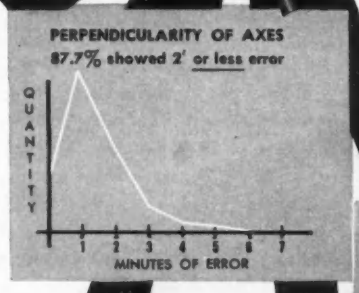
Editors Bill Vannah and By Ledgerwood sloppily enjoy their steamers at Capt. Starn's in Atlantic City, while the decorous business staff looks on in envy. Clockwise from the front: Bill Buehl and Milt Steinbraker, district managers for Philadelphia and Chicago, respectively; John Zisch, advertising sales manager; By Ledgerwood, managing editor; Keith Aldrich, research and promotion manager; and Bill Vannah, chief editor. Occasion was one of lighter moments of McGraw-Hill-wide meeting in Atlantic City.

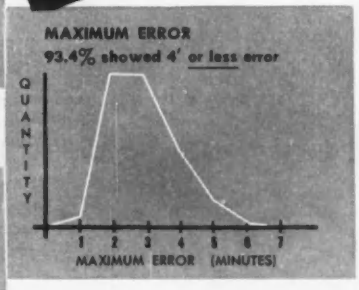
First-hand coverage of IFAC congress

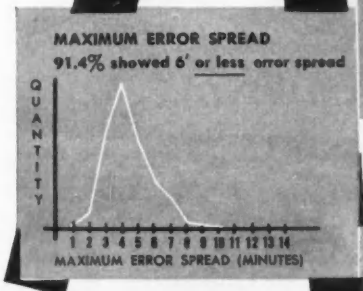
Keep your eyes on August "What's New" for detailed coverage of IFAC's First International Congress for Automatic Control, June 27 to July 7, 1960. European Editor Derek Barlow, representing CONTROL ENGINEERING at this Moscow meeting, will cable hot information in time for the August issue. For early impressions on the Russian welcome see the report from our Moscow correspondent on page 27.

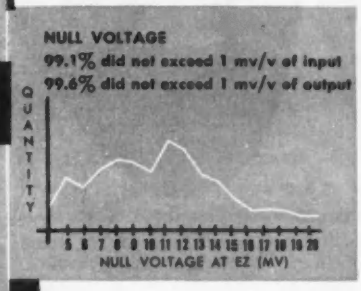
HIGHEST ACCURACY IN PRODUCTION QUANTITIES

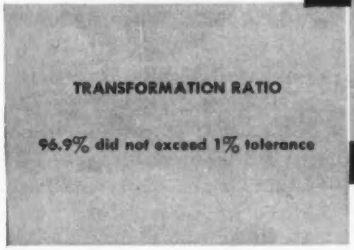
PRECISION COMPUTING RESOLVERS








NULL VOLTAGE
99.1% did not exceed 1 mv/v of input
99.6% did not exceed 1 mv/v of output
QUANTITY
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
NULL VOLTAGE AT EZ (MV)



Occasionally we see advertised rotating components of fantastic accuracy. Sure, we make these *hand built* units too. But they are usually very expensive, of a large size, and you get delivery a few units at a time.

CPPC will sell you 1000 (or 10,000) of these Size 11 Precision Computing Resolvers, holding the very high accuracies shown on this page, and at a price which will surprise you. If you know the rotary components market, you know that we have been able to substantially lower traditional prices in the past.

Two modern rotary components facilities (Clifton Heights, Pa. and Colorado Springs, Colo.) assure deliveries in 45 days on quantity orders. Samples from the shelf immediately. Telephone Hilltop 9-1200 or our representatives.

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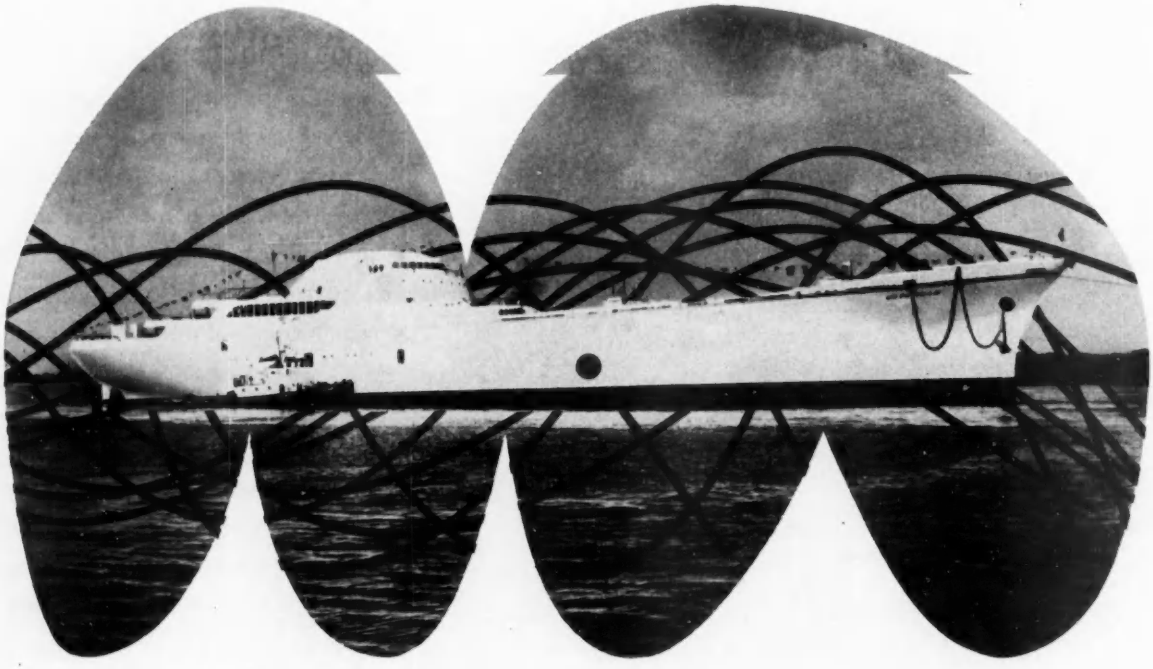
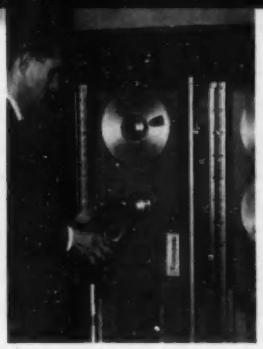
For the Babcock & Wilcox Company:

a Burroughs 205 computer backed the team that introduced atomic power to the merchant fleet...





another Burroughs computer is helping build one of the world's largest steam boilers...

and still another is speeding a vast research and development program

History has already earmarked July 21, 1959, in remembrance of launching the N. S. Savannah—the world's first nuclear merchant ship. This graceful queen of the seas may well be the precursor of a vast atomic merchant fleet—ships operating quietly and efficiently on nuclear engines.

Yet months before touching water, the Savannah's nuclear propulsion system was obtaining hundreds of "trial runs" on a Burroughs 205 computer at The Babcock & Wilcox Company's Atomic Energy Division in Lynchburg, Virginia.

Long before the vessel was launched these computer runs predicted changes that were to take place in the heart of the nuclear reactor. With the aid of these data, decisions were made as to the optimum size of the reactor, the lifetime of the fuel elements, amount of fuel needed, approximate costs and myriad other specifications.

Of course, a simulated run could have been made with a desk calculator—but it would have taken one year to complete a single run. The 205 has completed the same job in just a few hours.

This is the latest installment in a success story that started in November, 1955—the installation date of the Burroughs 205 at the Atomic Energy Division. Aside from the N. S. Savannah project, the same computer contributed immeasurably to other reactor designs, and other engineering work involving stress and thermal calculations, plus cost accounting data processing.

A recognized pioneer in the application of electronic data processing equipment, B&W was one of the first companies to develop its own automatic programming system. The effect of this powerful programming aid—called DUMBO—is to extend the capabilities of the 205 to hundreds of engineers without special knowledge of computer characteristics and techniques.

B&W engineers at Lynchburg are now able to write a plan for the computer to follow; DUMBO then automatically translates the plan into 205 language for electronic data processing.

With valuable 205 experience on design problems of a different nature, B&W's Boiler division (at Barberton, Ohio) has now installed a larger Burroughs 220 computer system to handle its increasing activities. Now in the design stage, with the aid of the 220, is one of the largest steam boilers ever conceived. When finally erected, the new steam boiler will stand as high as a 22-story skyscraper, produce 4,900,000 pounds of steam per hour, and generate sufficient power to light a city of 5,000,000 population.

Whether designing mammoth power equipment or a small industrial boiler, the Burroughs 220 has become a vital tool from initial bid through final design. The Burroughs 220 is helping to win orders with fast-but-realistic proposals, slashing costs and lead time at every possible opportunity.

B&W, whose product range includes tubular products, refractories, and marine boilers, as well as stationary steam generators, is also spearheading the development and construction of nuclear stationary and marine propulsion power plants. In all these programs, B&W depends upon the most modern analytical processing equipment.

At the company's Research and Development Center based in Alliance, Ohio, a third Burroughs computer has recently gone "on the air." This Burroughs 205 was purchased to process data for a variety of research experiments in the fields of heat transfer, fluid flow, stress analysis, and thermodynamics. Its immediate impact has been to free creative engineering talent from routine calculations and to reapply valuable human resources to the pursuit of new sources of economical energy. This 205 has already developed research data otherwise inaccessible.

All three Burroughs computers are helping B&W to meet a wide range of the nation's power requirements in the most efficient and economical way possible. Hundreds of other industrial and commercial users are confirming similar experiences.

Burroughs' complete line of electronic data processing equipment is backed by a coast-to-coast team of computer specialists, able to advise on how Burroughs can help you in your business. For additional information, write General Manager, Data Processing Systems Group, Detroit, Michigan.

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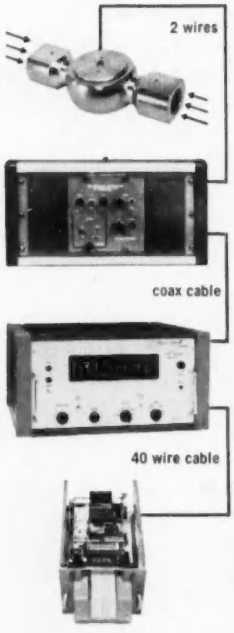

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T-32

FEEDBACK

AN INVENTOR'S STORY

American tells how Russians diligently apply his blast furnace control inventions.

We invent, "they're" diligent.

TO THE EDITOR—

It is a fact, as Millard Gaut reported on page 10 of CtE's April issue, that I have patents in this and other countries on the pressure drop control of blast furnaces. The first of these, U. S. Patent 2,625,386, was filed in May, 1947. It includes the arrangement shown and described in your story [May 1959, p. 31, Ed.] to control pressure drop by the regulation of certain variables that affect pressure drop; these include blast humidity, blast temperature, blast volume and furnace or top pressures, blower speed and the injection of oxygen and gases other than air, in response to changes in pressure drop. The patent discloses various modes for the control of total pressure drop through the entire stock column, or between various levels of the stock column. Descriptions of actual installations of the control method were printed in the AIME *Blast Furnace Proceedings* for 1950 and for 1952. The *Association of Iron & Steel Engineers Yearbook* for 1953 also printed a paper that I gave some time before.

I have been aware that the Soviets copied the invention at their Zaporozhstal' Works in 1954, at their Kuznetsk Metallurgical Combine in 1956, and elsewhere, as reported in CtE. When I applied for foreign patents some years ago, I excluded the USSR, because it was my impression that they did not grant patent protection to Americans at that time, nor could I have exploited the invention in Russia.

In view of recent comparisons between American and Russian technologies, of particular interest to me was a report on the Zaporozhstal' and Kuznetsk tests, printed in the December 1958 issue of *Stal'*, Vol. 18, No. 12, pages 1071 to 1077. The report indicated that difficulty was experienced with the control method on the basis of total pressure drop measurement through the entire stock column; this difficulty was attributed in part to differences in the effect of top pressure changes, for example, to correct for pressure drop changes in the lower part of the furnace as compared to the effect in the top part of the furnace. It was also admitted that the corrective responses of the control and furnace systems were very slow. Better control was reported on the basis of measuring partial pressure drops between various levels of the furnace. Our experience indicates that satisfactory control may be obtained by either method; we have not experienced the difficulties reported by the Russians in *Stal'*. Unfortunately, their report showed various pressure drop records only, without control, under smooth and under irregular furnace conditions but showed no records of modulated variables nor of controlled pressure drop. It was our impression that they found the control system inadequate to handle the furnace conditions. My curiosity was further aroused in June 1958, when the Soviets had an exhibit at the Automation Show at the Coliseum in New York. I was advised they wished to contact me, but I was not available. As they had tested the pressure method earlier in 1958, I assumed that the Soviets still were having control difficulties and wanted my advice.

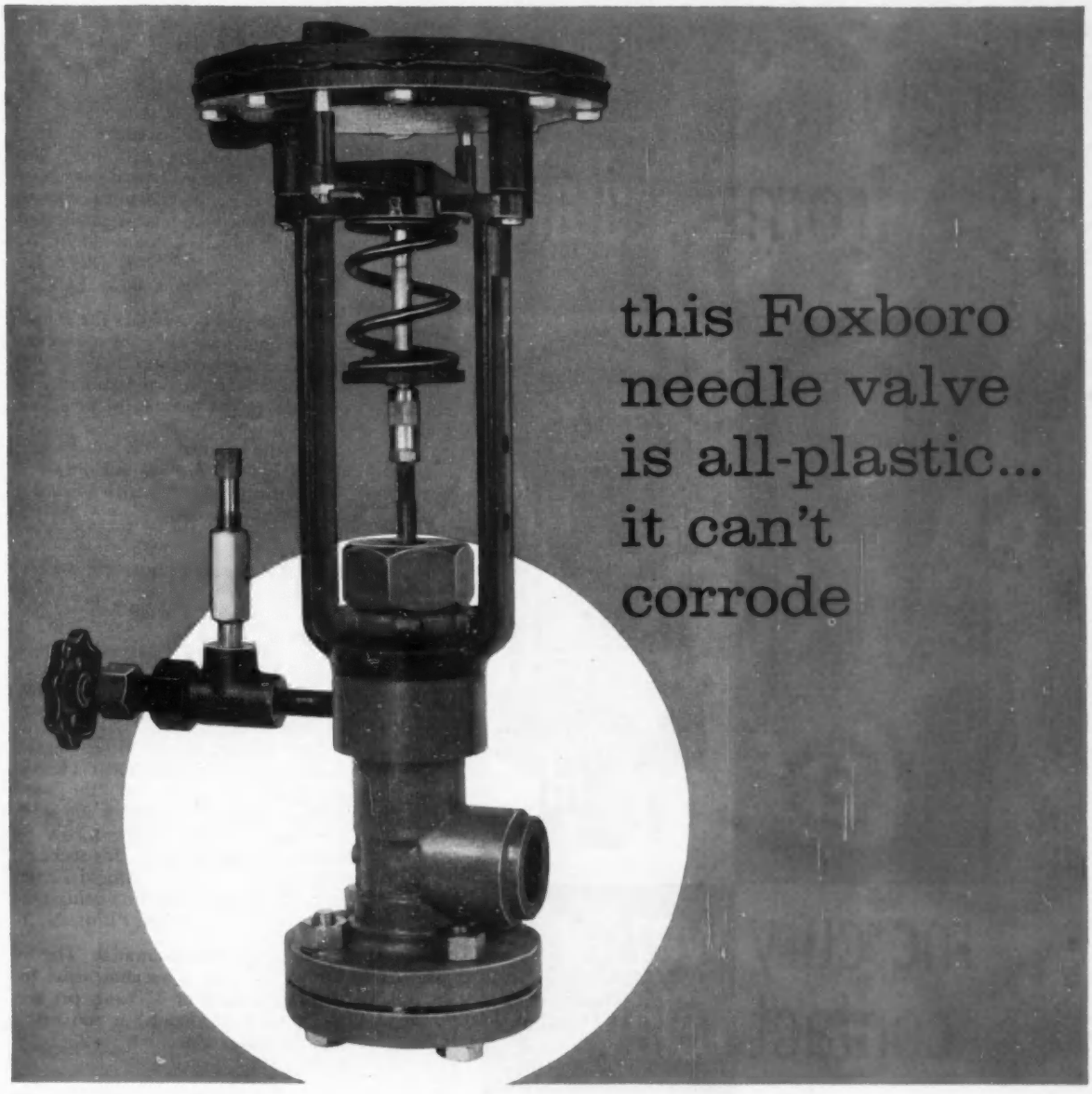
It may be of further interest to mention that the Soviet blast humidity control system which Mr. Ziebolz reported in the November 1958 issue of CtE as currently being used in Russia is based on another of my inventions, described in U. S. Patent No. 2,489,455, which I assigned to the Bristol Co. When the Soviets learned that we had developed this system during the second World War, they arranged to purchase a number of them through Amtorg. We learned that they later built their own units for other furnaces. To the Soviets' credit, it must be said that they were quick to recognize the advantages of using controlled blast humidity to improve blast furnace performance and production. It appears that they are applying the same diligence in the use of pressure drop control.

Otto J. Leone
West Newton, Pa.

What Japanese instrumentation?

TO THE EDITOR—

The article, "Japan Joins the Giants," which appeared in the April issue of CtE (pages 101 and 103),



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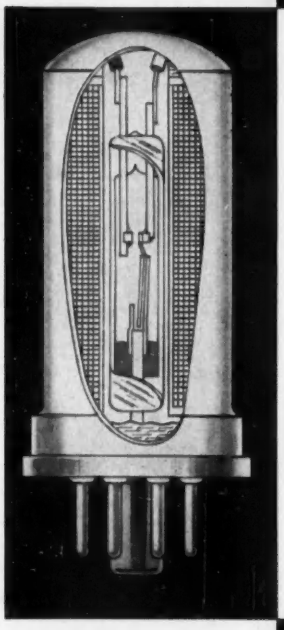

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FEEDBACK

was most interesting to me.

Is there any trade journal, in either Japanese or English, that would contain information on typical instrumentation that is manufactured and exported from Japan (some publication similar to CONTROL ENGINEERING)?

J. L. Moore Co.
Williamsville, N. Y.

Japanese publications in the control field do not have as broad a coverage for the control engineer as does CtE, but the editors of two Japanese publications might be able to help you. Ed.

Automatic Control
The Society of Automatic Control
c/o Institute of Industrial Science
University of Tokyo
Tokyo, Japan

Journal of Society of Instrument Technology
Dept. of Applied Physics
University of Tokyo

Faster, faster speed the cards.

TO THE EDITOR—

The article on the Los Angeles County balloting equipment (February, page 67) states that "the latest IBM card sorter will feed 1,000 cards a minute." In fact, however, our 84 Sorter operates at twice this speed.

Arnold Lerner
IBM Data Processing Div.
White Plains, N. Y.

Throw out the stopwatch. The 84 Sorter, too, uses a vacuum assist for nonstop feeding of 33 cards per sec. Don't be there, hands, or you won't have to move. Ed.

Info, please—metal detector

TO THE EDITOR—

We are in urgent need of information as to manufacturers making control equipment to shut down a rock crusher when any metal object is placed in the conveyor belt.

German Ortiz
Rio Piedras
Puerto Rico

One or more of the following organizations may be able to help you. Eriez Mfg. Co., 7 E. 12th St, Erie, Pa, manufacturers of metal detectors specifically for use with conveyors; Metrol, Inc., 17 E. Holly St., Pasadena, Calif., contact Richard Hochschild, pres.; Ramsey Engineering, 842 Raymond Ave, St. Paul, Minn., contact John Reide, pres. Ed.

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the NEW Franklin Model 500A Digital Multimeter

all-electronic operation . . . 0.1% d-c accuracy

From its extra-heavy-duty case (0.090" aluminum) to its improved all-electronic circuitry . . . the Model 500A offers more advantages than any other digital multimeter available today. No idle boast! The effectively infinite d-c input resistance (on ranges below 1200 V) permits accurate readings across resistive loads that would be disturbed by the best conventional instrument. Then again, there's the conservative 0.1% d-c accuracy . . . better than some bridges. Yes—the 500A has the usual features too; like the automatic polarity indication that lets you read negative or positive d-c without reversing leads. The brief specs tell more . . .

MODEL 500A DIGITAL MULTIMETER
$1850 F.O.B. BRIDGEPORT, PA.

request data sheet 2013

brief specifications

RANGES	DC: 0.000 to 1.200, 12.00, 120.0, 1200 V positive or negative (automatic polarity indication). AC: Same as dc ranges (rms value of 30 to 10,000 cps sine wave). OHMS: 0.001 to 1,000 K ohms.
ACCURACY	DC: Better than ±0.1% of full scale. AC: Better than ±0.2% of full scale up to 120 V and 200 cps. Better than ±0.5% of full scale above 120 V and 200 cps. OHMS: Better than ±0.2% of full scale.
INPUT IMPEDANCE	DC: 20 megohms nominal. (Effective input impedance on other than 1200 V range approaches infinity.) AC: 20 megohms shunted by 400 mmf.

POWER REQUIREMENTS	105 to 125 V, 60 cps, 250 W.
DIMENSIONS	Portable model (illustrated): 11¾" H x 11⅜" W x 18½" D. Rack mounting model 19" W.
WEIGHT	45 pounds.
FINISH	Smooth gray baked enamel. White engraved panel designations.
SPECIAL FEATURES	Printer output provisions. Static parallel; binary coded 1-2-2-4 decimal output. (Other codes optional extra.)

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You count best when you count on FRANKLIN

D. Lawrence Pierce
heads nema's newest section

When the National Electrical Manufacturers' Association formed a new Industrial Automatic Systems Section in January 1959, they elected as the section's first chairman, D. L. Pierce, a control engineer who has spent almost 35 years designing and applying industrial controls. Over this span, Pierce has watched the emphasis move from simple magnetic contactors to solid state techniques for feedback control. And he has moved with them, chalking up a list of more than 30 patents on control equipment.

Born and bred in the midwest's "water wonderland", Pierce graduated from the University of Michigan in 1925 with a B.S. degree in electrical engineering. After graduation he headed for Pittsburgh to work for Westinghouse. For the first few years he maintained a stiff schedule as a Westinghouse engineering trainee and at the University of Pittsburgh, where he managed to amass some 30 credits in graduate engineering and economics. After only one year with the company, he assumed the title "control design engineer" and has been engaged in the design, application, production, and standardization of industrial controls ever since.

Pierce's early indoctrination in Pittsburgh stuck. This month he celebrates his 35th year with Westinghouse Electric Corp. Since 1956 he has been the assistant manager of the entire Control Dept. at the company's Motor and Control Div. in Buffalo.

His accomplishments over the years are a matter of record. His name—without the *D*—must certainly be familiar to the people in the U. S. Patent Office. The reason for the dropped *D* is probably best known to patent attorneys. Like the *S* in Harry S. Truman, the *D* in D. Lawrence Pierce is an initial and nothing more. Pierce's friends have solved the problem by calling him Danny. According to Patent Office rules, however, a patentee can have either two or three names but cannot use an initial in lieu of a first name. At any rate, the name Lawrence Pierce appears on more than 30 patents starting with one dated July 10, 1934 describing an electromagnetic contactor, to one dated January 28, 1958, covering a limit switch operating mechanism. Several others are still pending.

In the last four or five years, he has spent much of his time carrying the Cypak static switching story to engineering groups throughout the country—to the winter meeting of the Association of Iron and Steel Engineers in San Francisco, to sectional meetings of the Industrial Electrical Engineering Society in Detroit, to the Instrument Society of America in Buffalo, and to countless meeting of the AIEE.

Recently, his activities on behalf of the National Electrical Manufacturers' Association have been taking up more and more of his time. NEMA and its objectives are, of course, not new to Pierce. Since 1931, he has been an active member of at least one of its sections. In 1950 he began representing Westinghouse on

the General Engineering Committee of the Industrial Controls Section and has been active on several of its subcommittees. In fact it was while working as a member of Subcommittee 16 on Electronics and Regulators, that he realized that this tiny subcommittee was the only NEMA group seriously interested in standards for feedback control systems.

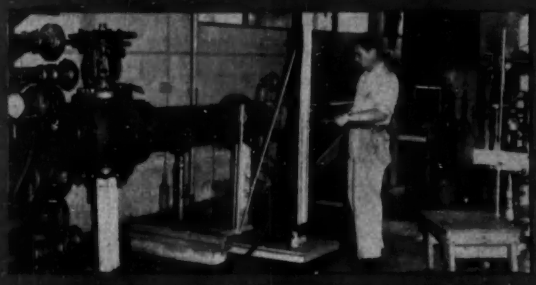
At the time both GE and Westinghouse were working on new solid state techniques for industrial control applications, and both recognized the need for a brand new NEMA section to serve not only their own requirements but also those of the many other companies that would soon be offering packaged feedback systems. It took a lot of educating, but finally in January 1959 NEMA's Board of Governors established the Industrial Automatic Systems Section. Pierce was elected chairman of the section and continues in that capacity today.

Today when he's not busy as section chairman or as a member of one of its committees or subcommittees, Pierce may still be tied up in NEMA work. Last November, NEMA underwent some reorganization; sections were combined to form divisions, and divisional boards of directors were established. Even before these changes were finally adopted, Pierce had already been nominated by his own Industrial Automatic Systems Section for a spot on the board of the still-to-be-established Industrial Equipment Division.

In all, Pierce estimates that he spends about half of his time away from his desk in Buffalo; regretfully, none of this has been vacation time. A friend with a place in Gulfport, Fla., bordering on the third fairway of a golf course, has extended a more or less open invitation. If or when Pierce will accept the offer is anyone's guess. His only comment—"not this year".

MODERN PLANT

MODERN MACHINERY



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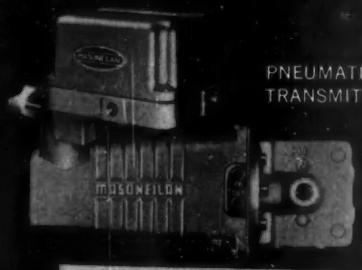
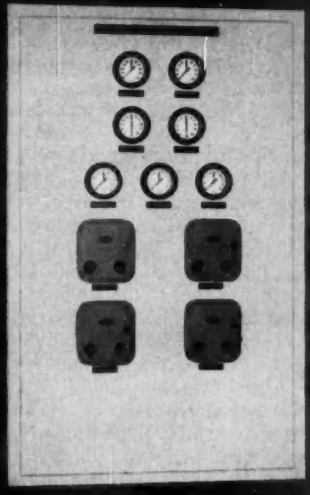


PNEUMATIC TRANSMITTERS



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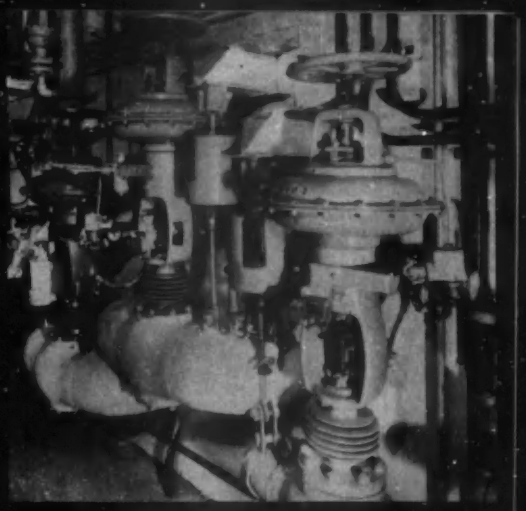

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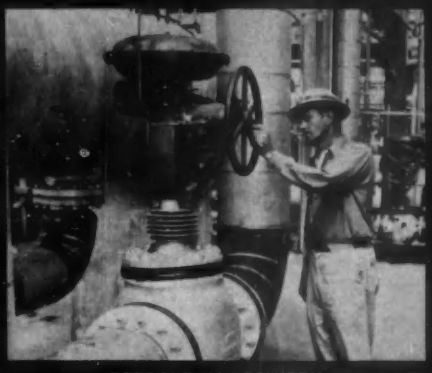

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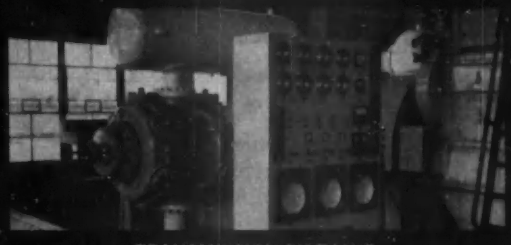

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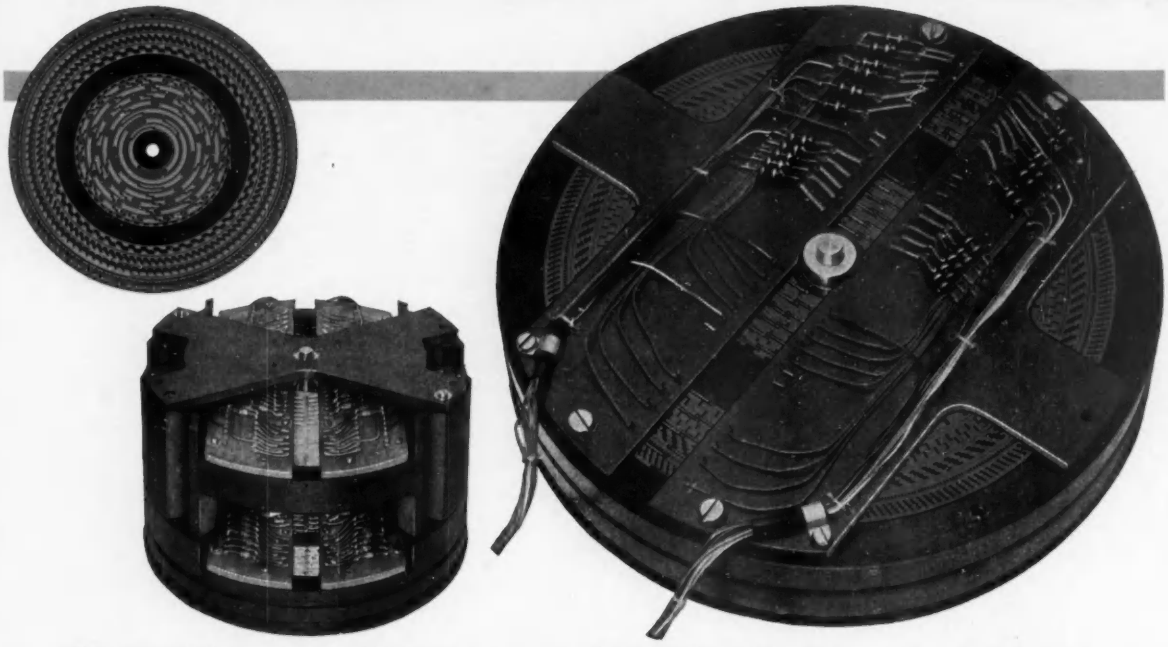
CIRCLE 17 ON READER SERVICE CARD



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- **several models in 4 2 2 1 code***

Norden offers a wide variety of binary-coded decimal shaft encoders for commercial applications. These encoders meet or surpass military specifications, and have patented, self-selecting V-brush logic.

Code disc patterns produce a totally unambiguous 8-4-2-1* binary decimal readout ranging from 2 to 6 decades. The units can be used for feeding high speed computers and servo systems . . . data logging, machine tool automation, test stands, flight check-out. Self-selecting V-scan increases reliability and life while saving space and reducing complexity and cost. Load carrying brushes never commutate. These are the only encoders that have provision for automatic self-checking gating devices for virtually 100% error monitoring.

*Several models are available in *4-2-2-1 CODE* which provides a nine's complement and makes available in a single encoder an increasing numerical count for both directions of shaft rotation.

MODEL NO.	TOTAL COUNT	REVOLUTIONS FOR FULL COUNT	ACCURACY (1 part in)
ADC-ST2-BCD	10^2	1	100
ADC-3-BCD	10^3	10	1,000
ADC-4-BCD	10^4	100	10,000
ADC-5-BCD	10^5	1,000	100,000
ADC-6-BCD	10^6	10,000	1,000,000
ADC-ST3-BCD	10^3	1	1,000
ADC-5-BCD-1000	10^5	100	100,000
ADC-3-36BCD	360	3.6	360
ADC-4-36BCD	3600	36	3,600
ADC-5-36BCD	36,000	360	36,000
ADC-6-36BCD	360,000	3,600	360,000
ADC-ST3-36BCD	360	1	360
BRL-5	360,000	1	360,000
ADC-ST2-BBCD*	10^2	1	100
ADC-3-BBCD*	10^3	10	1,000
ADC-4-BBCD*	10^4	100	10,000
ADC-5-BBCD*	10^5	1,000	100,000
ADC-6-BBCD*	10^6	10,000	1,000,000
ADC-3-36BBCD*	360	3.6	360
ADC-4-36BBCD*	3,600	36	3,600
ADC-5-36BBCD*	36,000	360	36,000
ADC-6-36BBCD*	360,000	3,600	360,000

Write Norden or call TRinity 4-6721 for complete specifications

NORDEN

DIVISION OF UNITED AIRCRAFT CORPORATION

Milford Department, Wiley Street, Milford, Connecticut

Newsbreaks In Control

- **Flight Test in Nose Dive**

  San Diego—Biggest problem in flight test these days is what to do with flight test engineers. At the ISA National Flight Test Symposium here, attendance slipped as flight test programs have been curtailed along with the decline in aircraft activity. Only Grumman reported boom activity. Flight test groups at Boeing, Douglas, Lockheed, and Convair have been reduced sharply. One place flight testers are moving: oceanographic studies and underwater instrumentation. At the symposium, to illustrate the trend, Consolidated Electrodynamics Corp. unveiled a new magnetic tape recorder. Type I-740, designed for use on a submarine.

- **First Industrial Adaptive Control**

  New York—First adaptive control hardware in an industrial system will be tried out in the automatic startup control and operation control at the Little Gypsy Station of Louisiana Power and Light Co. Adaptive control will be the approach used by control supplier, Daystrom Systems, to optimize combustion process over a wide range of boiler parameters.

- **Biggest Wiedeman Press to Get Automatic Control**

  Buffalo—Westinghouse Electric Corp. is going back into the field of numerical control of machine tools. Westinghouse is building a numerical control system for the biggest Wiedeman press ever built.

- **GE to Market Data Processing Computers**

  Phoenix—General Electric Co., largest user of data processing computers, will market a new medium sized business data computer under its own nameplate. GE's Computer Dept. already builds a large scale system which National Cash Register Co. markets as the NCR 304. The new machine, the GE 225, will first be installed in 10 other GE divisions.

- **Navy Unveils Underwater Manipulator**

  La Jolla, Calif.—RUM, Remote Underwater Manipulator, being evaluated by the Navy is remotely controlled by multiplexed high freqnency signals. The operator watches progress of the converted tank via closed circuit TV. The vehicle can operate at ocean depths of several thousand feet at up to 5 miles from shore for underwater research studies.

- **Honeywell Reveals Digital Process Control Computer**

  San Francisco—Minneapolis-Honeywell's H290 computer has 18-bit word length with parallel transfer to speed operation. Main core memory stores 1,024, 2,048, or 4,096 words. Drum memory—4,096 or 8,192 words—is optional. Program protection prevents disturbing the information on drum memory. A list of 63 instructions facilitates frequently occurring arithmetic operations. Execution times in milliseconds of typical instructions are: add and subtract, 0.14; multiply, 0.80; square root, 2.6.

A CtE NEWS ROUNDUP

The Coming Boom in Teaching Machines

A $100 million a year market for automatic teaching machines is predicted within ten years. Here's a report on the scramble to get in on the ground floor.

In a California laboratory, a small general purpose electronic digital computer has been programmed so that it monitors and modifies student performance in a classroom. The experiment represents one aspect of a new trend in teaching circles.

The military, industry, and general education are eyeing what could easily be the most revolutionary change that education has ever undergone: the automatic teaching machine that will mechanize the training process. Preliminary experiments indicate that the self-teaching devices can speed up training by at least 30 percent with no sacrifice of teaching quality.

As a business the stakes are high. In general education alone, some day, each of the 23,000,000* elementary school students, 10,000,000* high school students, and 3,000,000* college students attending classes each year in the United States will receive part of their schooling from automatic teaching machines. In addition, the military has a prodigious job of keeping its enlisted technicians up to date with the complex equipment they must operate and maintain. And industry has a similar tremendous training problem—upgrading workers to take advantage of automatic equipments and paper-handling systems.

Such an inviting potential has spawned a struggling new industry which is betting millions of dollars that automatic instructors will win acceptance despite some considerable resistance. As yet the infant industry has reaped only paltry returns, but builders of teaching machines expect to crack the military market this year, then industry, and finally the rich school market. One company predicts $100 million annual sales by 1970.

* 1958 figures—and population's growing.

• **Strange bedfellows**—Today's teaching machine industry has some strange and interesting characteristics. Composed of such companies as Rheem Califone Corp., U. S. Industries, General Atronics, and Systems Development Corp., the industry is heavily dominated by psychologists who have a tendency to disagree with each other as to approach, principle, and equipment for automatic teaching. And they argue in a technical jargon quite unintelligible to outsiders.

About the only thing the psychologists agree on is the tremendous advantage of teaching machines for everybody with a training problem. Teaching machines, they say, will speed up training so that a teacher can handle more students without sacrificing the quality of instruction. In fact, the psychologists will offer five good reasons why teaching machines can upgrade the quality of instruction:

▶ There is a constant interchange between program and student; the machine keeps the student busy and alert.

▶ The machine insists that a student understand thoroughly a given point before moving on to the next.

▶ The machine presents that material for which the student is ready.

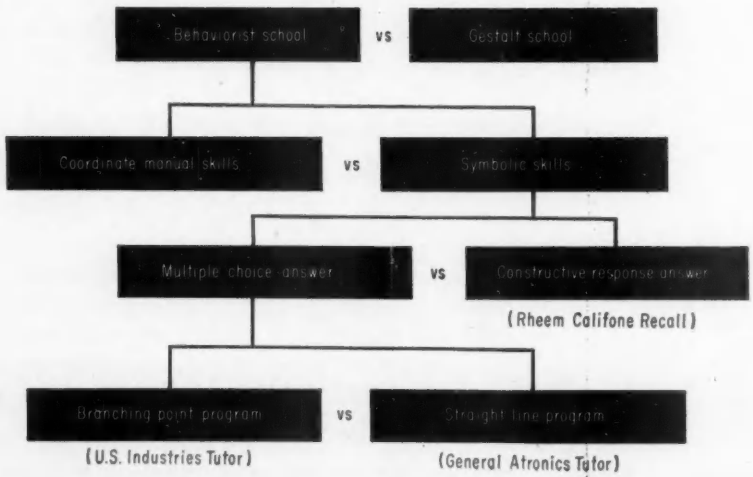
▶ The machine helps the student come up with the right answer. It does this by the orderly construction of the training program and by hinting, prompting, and suggesting.

▶ The machine *reinforces* (emphasizes or rewards) the student for every correct response, using this feedback to shape future learning.

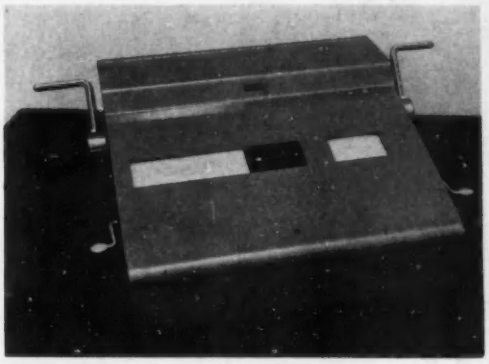
These five points sound very much like the description of a good private tutor, and the similarity has not been lost on the fledgling industry. Both U. S. Industries and General Atronics call their machines "The Tutor".

All the machines have one point in common. They teach by exposing the student to a brief written explanation of a point and then checking his understanding of that point by asking him to make some kind of response—fill in a blank or answer a multiple choice question. Cost of the machines vary: both Rheem and General Atronics sell their devices for

THE DICHOTOMY OF TEACHING MACHINES



WHO WILL WIN THE TEACHING MACHINE RACE?



Rheem Califone Corp? With its mechanically operated RECALL machine, based on Dr. B. F. Skinner's write-in response technique. Student writes in answers on the strip at right side of machine, then checks written response with correct answer.

U. S. Industries? With its electromechanical TUTOR Machine, based on the scrambled book. Student chooses an answer by pushing a button. Mechanism moves a new page before him. If he is correct, he progresses to the next point; if he is incorrect, he will be told why.

General Atronics? With its mechanically operated TUTOR, based on a straight line program. Explanations and questions are arranged on cards. To answer student pushes button. If answer is correct, card drops down. If student is wrong, nothing happens.

Somebody else? With an electronic teaching machine like this device built by Solartron Industrial Controls in England. Also reported entering the teaching machine field with electronic devices are: Hughes Aircraft, Minneapolis-Honeywell, and Varian Associates.

about $200; U.S.I.'s unit sells for from $3,900 to $5,000.

• **Translating the jargon**—Some of the resistance to teaching machines stems from potential users' inability to understand the technical jargon which psychologists have applied to describe what these machines can do. For example, of those already announced, Rheem's teaching machine relies on the *written response*, U. S. Industries' is based on the *scrambled book* technique, and General Atronics' follows a *straight line program*.

To understand what all that means requires a brief glimpse at some psychological fundamentals. The chart shows one approach. Almost all the disagreement about the teaching machines stems from opposite viewpoints as to the school of psychological thought, the type of skill to be taught, the kind of answer required, and the kind of program by which the machine teaches.

• **Academic roots**—If all this sounds academic, there is a good reason for it. The teaching machine industry literally was born on college campuses. Most people recognize that Professor Sidney L. Pressey (now at the University of California at Los Angeles) built the first automatic teaching machine in the 1920's. Pressey's machine died a victim of cultural and educational inertia.

His concept remained interred until a Harvard professor, B. F. Skinner, breathed new life into it with an outstanding article in *Science* magazine in 1958. Skinner has strongly influenced most of the others working in the teaching machine field. The recent boom in activity started right after his 1958 article appeared.

Each of the companies which offers a commercial teaching machine has allied itself to an outstanding psychologist. Skinner himself is working with Rheem. U. S. Industries has employed Norman A. Crowder, a research psychologist who got his teaching machine ideas while working for the Air Force Research and Develop-

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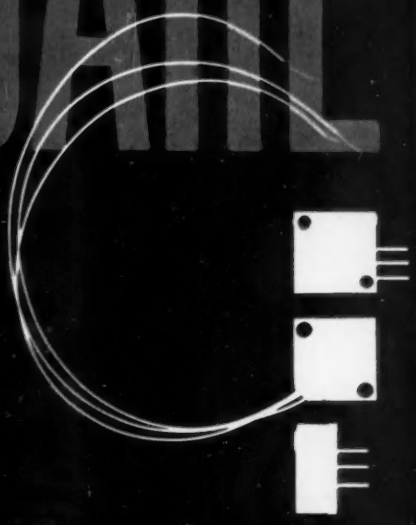

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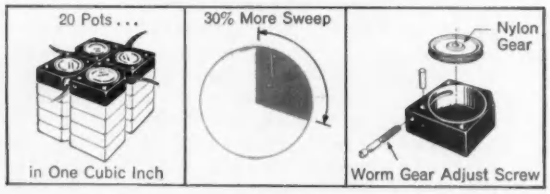

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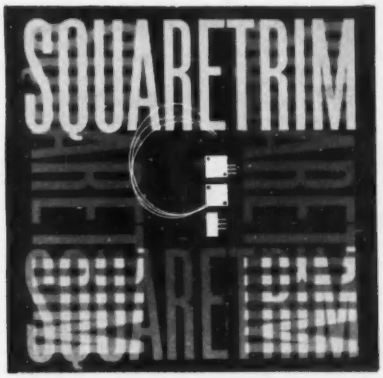

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WHAT'S NEW

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ment Command. In Philadelphia, General Atronics leans on some of the researches of Eugene Galanter at the University of Pennsylvania.

Designs of these machines have been based on some intriguing psychological experiments, like the one Galanter performed to measure the relation of learning and the time interval between answering a question and discovering the correct answer. In the experiment students attempted to predict the rules by which lights were illuminated in sequence. Galanter determined that the number of trials before a student learned the rule was minimum if he learned the answer ½ sec after he made his prediction. In addition, Galanter observed that the number of trials mushroomed as the time interval increased. The student required 10 times as many trials if the answer came 10 sec after prediction and 100 times as many trials if the answer were shown a minute later.

To take advantage of this characteristic, General Atronics has geared its machine so that student can learn right answers within half a second of his making a choice. GA's Vice President, Robert W. Roop claims that this gives a multiple choice machine an inherent advantage over the write-in response device. In the write-in response, he says, there always is a delay from the time the question is asked until the student learns the answer—a delay caused by the actual writing down of the answer and the checking of it.

• **Campus boom**—A lot of the activity in teaching machines is still taking place on campuses. New companies are springing up from the amalgamation of faculty capabilities. For example, two University of Pittsburgh faculty members recently moved to Albuquerque, N. M., and set up Learning Machines, Inc.

Here is a rundown of some of the recent teaching machine activity in academic circles:

▶At UCLA, Dr. Pressey and Dr. Keisler have converted a Navy teaching device (originally used to teach aircraft identification) to teach arithmetic to fifth and sixth grade students.

▶Devereaux Foundation (Devon, Pa.) has a spelling program for elementary school students.

▶Oberlin College is programming psychology, genetics, music, logic, and mathematics for teaching machines under a Ford Foundation grant.

▶Earlham College's John Barlow has started a three year study of automated teaching; it will be financed by the U. S. Department of Health, Education, and Welfare.

▶Hamilton College's John Blyth has programmed five elementary courses and is ready to try programming French, German, mathematics, philosophy, and psychology.

▶University of Illinois is researching possible devices for automatic teaching under a U. S. Office of Education grant.

▶Northwestern University is testing a combined visual and aural device for teaching languages.

▶Harvard University, under Dr. Skinner's eye, has launched one of the biggest programs. Courses have already been taught at Harvard and other Boston schools with automatic programs.

• **Program is the thing**—As results come in from these college studies, there is a growing indication that the piece of hardware that is the teaching machine may not be as important as the program to teach a particular subject. Some people think that once a basic program exists, it can be modified to be used on any of the machines.

Certainly programming is a key bottleneck today. At U. S. Industries a spokesman said it couldn't even estimate what a program might cost. The costs might vary widely depending on the subject. What USI offers is a specialist trained in the scrambled book technique to work along with a specialist supplied by the user in the subject to be programmed.

General Atronics estimates a cost of $20,000 to prepare a straight line program for a one semester course to be taught on its machines. GA figures it takes a man-year of labor to program such a course. And the straight line program is considered an easier one to prepare than the branching program. GA has started to program a course to teach people to read Russian. Before it is finished, the course will have 3-4,000 steps.

The expense of preparing a program leads Roop to the conclusion that the teaching machine business may have to operate like book publishing. A company would program a subject it feels will sell to a large number of users so the cost can be spread broadly.

Despite some uncertainty about programs, industry is pushing ahead as fast as it can. Here is a partial listing of industry activity:

▶U. S. Industries has sold 18 machines to Wright Air Development Div. Its machine is also being evaluated by a life insurance company.

▶General Atronics' machine is being used in an experiment in Phila-

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WHAT'S NEW

delphia schools; the company is also trying to interest the armed forces.

▶Rheem Manufacturing Co. acquired Califone Corp., a maker of educational audio equipment, to form Rheem Califone Corp. To push teaching machines, the new company publishes a small learned journal called *Automated Teaching Bulletin*.

▶Schering Drug Co., as an outgrowth of operant behavior studies, is constructing an elementary algebra program, plans to continue with programs for intermediate algebra, plane geometry, and trigonometry.

▶Minneapolis-Honeywell has decided on an approach to teaching machines, but is keeping its method under wraps. Preliminary information indicates it will operate on a write-in response and use a general purpose digital computer to grade the students.

This last item hints at the opening of a whole new area of teaching machines. All the machines previously mentioned have been mechanical or electromechanical in nature. Electronics offers some exciting possibilities. One company (CtE, Nov. '59, p 144) uses an electronic teaching machine to train keypunch operators.

System Development Corp. has several teaching programs for use with a general purpose digital computer, the Bendix G-15. Fifteen or 20 students at a time operate keyboards that are connected to the computer. Explanations and questions are displayed to the students (they can be thrown on a screen by a slide projector) under the computer's control. The students answer the questions by pushing buttons on the keyboard. The computer then tells the student if he is right or wrong and evaluates each one's progress.

• **Sooner than you think**—All this activity indicates that teaching machines may be in widespread use sooner than most people think. Most companies feel that industry will be an earlier customer than schools.

In school circles the big resistance to teaching machines comes from teachers who are reluctant to admit that machines can replace them. And they can't. All the builders of teaching machines agree that their devices will never replace teachers completely. Said one, "The teaching machine is another educational tool like a laboratory manual. It doesn't take the place of a human teacher."

Once this idea permeates the educational world, builders of teaching machines expect that their golden days will arrive. —**Lewis H. Young**

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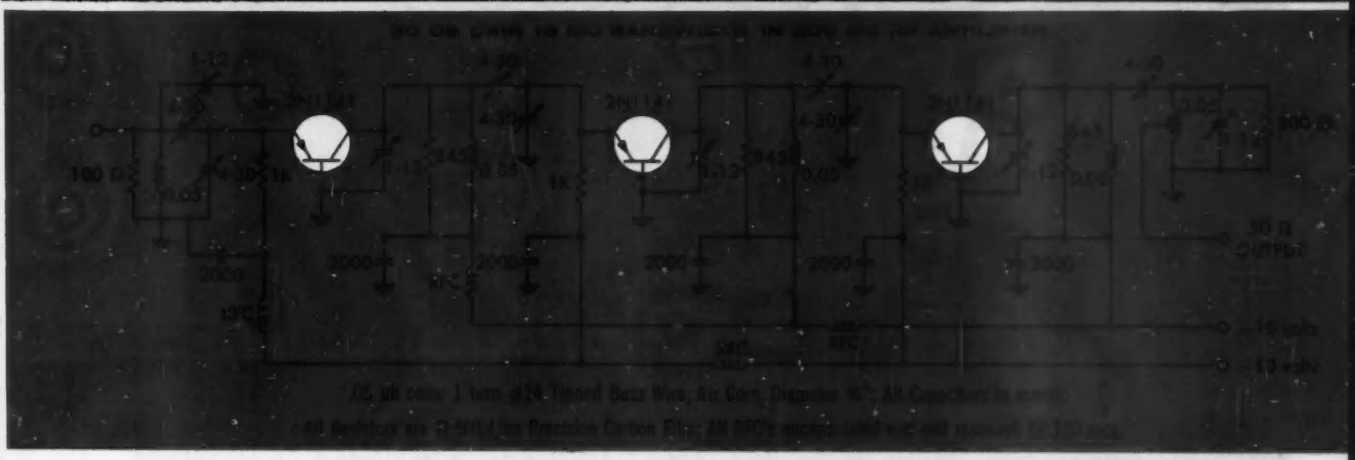

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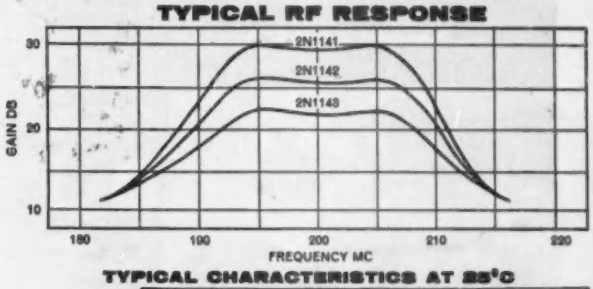

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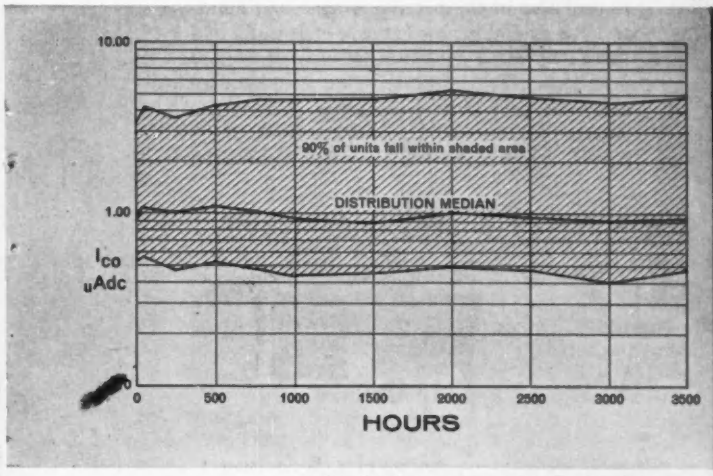
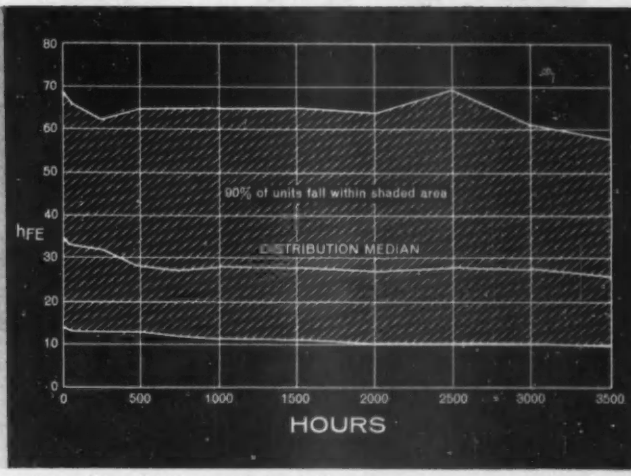
C_{Tc}	1.2	1.4	1.5	μμf
r_b'	65	80	110	ohms

UNIT TYPE 2N1142: I_{CBO} AND h_{FE} VS HOURS OF STORAGE AT +100°C

TEST LEGEND: Sample Size: 1000 units ▪ Test Condition: Storage at +100°C ▪ I_{co} Measured at: V_{CB} = −20v, I_E = 0 ▪ h_{FE} Measured at: V_{CE} = −6v, I_C = −10ma





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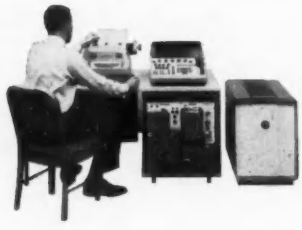

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Russians Ready Red Carpets—?

Moscow is bubbling over in anticipation of the first world congress of control. IFAC meeting shapes up as the biggest control meeting ever held.

MOSCOW—Russian workmen are polishing the heavy white marble columns that line the auditorium of Moscow University, a 32-story skyscraper that looks like a wedding cake, prettying up the room that will hold the first international congress of the International Federation of Automatic Control. The meeting starts here on June 27 and will run until July 7. A. M. Letov, deputy director of the USSR's Institute of Remote and Automatic Control and president of IFAC, expects 700 to 800 delegates to gather in Moscow to hear some 280 technical presentations. The program represents one of the heaviest concentrations of papers solely on control ever assembled.

The papers have been divided into three main groups: theory of automatic control, components, and applications in industry. Heaviest concentration will be in theory with nine technical sessions scheduled. Five sessions have been scheduled for component papers and six for applications. Preprints of all articles have been prepared in both English and Russian and will be available before the meeting.

Distribution of the sources of the papers indicates the international scope of IFAC. U.S. participants will present 73 papers; Russian, 80; Japanese 20; East and West German, 20; British, 30; Polish, 20; French, 15; Italian, 10; Czechoslovakian, six; and Red Chinese, six.

• **Rubbernecking Russian-style**—In addition to the sessions, the Russians are planning some extensive sightseeing for visiting delegates—both cultural and industrial tours. Visits will include the ancient Kremlin with its famous Vasily Blazhenny Cathedral, best remembered for its many cupolas, and many museums. Tickets will be provided for the world famous Bolshoi Theater ballet and opera.

Industrial tours will cover a variety of automatic lines in the fields of metallurgy, chemical processing, power stations, machine building, and instrument plants; applications of digital computers to control industrial processes; and some kind of self-adaptive control at work.

Because of the large number of delegates, the conference planners have been unable to make firm arrangements in advance. So visitors will have a choice of tours. Ivashin Grigorivich, a member of the conference's organization committee promises, "There will be enough, I assure you."

• **What to expect**—From the American standpoint, the USSR is still one of the most interesting countries in the world. And there are some startling contrasts for visitors to observe. For example, although the country will install 1,300 automatic production lines during the current seven-year plan, the abacus is still generally used instead of an adding machine.

Moscow is a city where taxi drivers jockey their miniature cars with the single-minded, pedestrian-beware air of a Manhattan Cabbie—in spite of relatively sparse traffic. It is a city where an extra ruble or two as a tip works wonders in improving hotel and restaurant service—despite official frowns.

Although tourism is becoming an established industry in the city, Westerners still excite friendly curiosity on the streets and in theaters and restaurants. (*Best bets for food: The National and the Budapest restaurants.*)

Bars and nightclubs, as they exist in the U.S., are nonexistent in the Soviet Union. Restaurants don't feature authentic Russian folk music; more likely the eating spot will be headlining an American-type jazz band. And it is the custom for a stranger to ask a woman to dance, even if she's with her husband.

Political discussions are taboo with casual Soviet acquaintances. They'll change the subject or pretend they don't understand if the subject arises.

Throughout the 11-day meeting, delegates will be under the care of Intourist, the state organization that handles outside visitors. Although the meeting takes place in the height of the tourist season, delegates will be receiving priority treatment because, in the science-oriented Soviet Union, the academician is king.

—Ernest Conine
McGraw-Hill World News

Moscow Bureau Chief Conine's dispatch was cabled before the U-2 spy-plane incident. As CtE went to press, it was impossible to foretell how the affair would affect plans for the congress.

Hungary's Control Plan Falters?

Headaches have cropped up in trying to meet the 100 percent control and measuring equipment production increase called for in Hungary's second five-year plan. Chief problems according to Gyorgy Striker, secretary of the Hungarian Scientific Association of Metrology and Automation, are engineering training, poor marketing arrangements and research, and poor system and project planning.

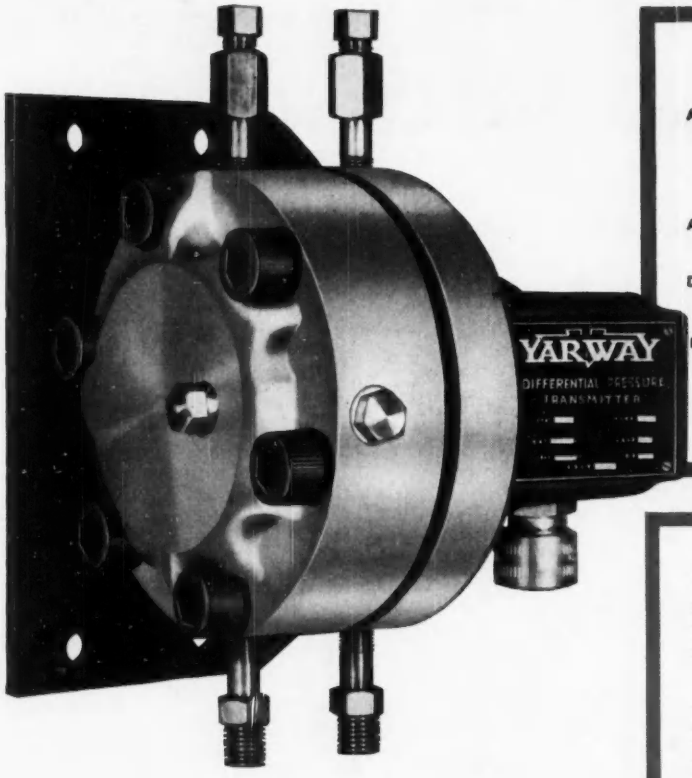
Striker estimates an additional 2,500 engineers and technicians would be required by 1965 to meet the targets. Hungary's present annual output is about 55 instrument engineers and 70 technicians.

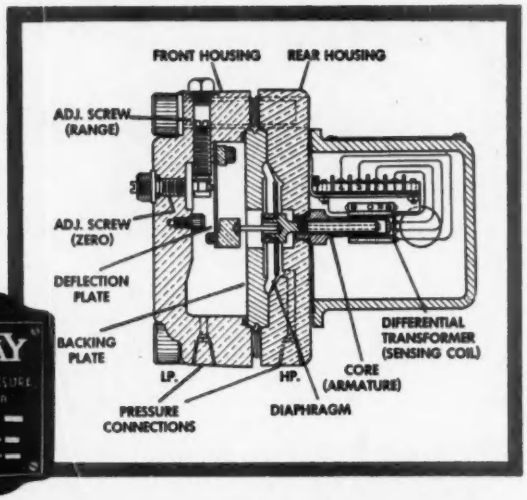
To meet what Striker calls "the otherwise seemingly realistic production and marketing targets" license arrangements and purchases of modern instruments from the West are scheduled. Hungary is behind and is particularly interested in digital equipment, miniaturization techniques, and systems engineering.

Also needed is flexibility in upgrading worker skills and in production planning to keep pace with unpredictable export demands—50 percent of the industry's output. Striker has suggested smaller branch work units.

Development of new instruments appears to be on schedule, but Striker's report heavily criticizes marketing arrangements. High prices cause stocks to accumulate, and not enough effort is spent on market research.

Striker has called on other Iron Curtain countries for more aid in materials and components and more technical information. **—Derek Barlow**





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Operations Summary Display with map of the world is main display for man-in-space project. Observers will be able to see the position of the capsule at any instant and what tracking stations have contact with the astronaut.

Flight dynamics officer will compare predicted and calculated performance with that which is actually taking place.

Flight surgeon's console produces complete electrocardiograph records and information such as blood pressure, pulse rate, and body temperature of the man in space.

Putting the Man-in-Space On Display

SAN DIEGO—

One of the stickiest problems in the proposed man-in-space project, say space scientists, is knowing where the man is at any instant after launch. When the U.S. starts its Project Mercury tests later this year, a full global tracking range will be in operation (CtE, July, 1959, p. 19). And all the information gathered by this complex tracking system will funnel into two control rooms, one at Cape Canaveral and the other in Bermuda.

Last month production was started on the display systems for these control rooms by the San Diego branch of Stromberg Carlson, Div. of General Dynamics, which has a subcontract from the Bell Telephone Laboratories to design, build, and install the systems. Information to be gathered includes not only the position data that is so essential but also such urgent information as physiological data on the astronaut, environment data inside the capsule, engineering data on the capsule, and flight data.

Stromberg Carlson, with industrial design consultation from the Henry Dreyfuss organization, has the responsibility for the operations room, including dimensions, lighting, color, displays, console equipment, and placement of equipment.

The man-in-space control room will be 60 x 60 ft with a 13½-ft ceiling clearance. At one end of the room, on a huge Operations Summary Display, will be portrayed the path of the manned capsule as it moves on its orbital flight path around the earth. Trend charts on both sides of the map

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WHAT'S NEW

will supply additional information.

• **Rows of observers**—Aligned in front of the operations screen are rows of monitors. It will take 14 men to keep track of one man in space. In the front, each with his own console, are the flight surgeon, who watches health factors, the capsule environment monitor, who keeps track of environmental conditions of the vehicle; the capsule communicator, who keeps in verbal contact with the astronaut; and the capsule systems monitor, who watches for system failures.

Sitting at second row desks: the recovery status monitor, who keeps track of the capsule when it moves into the recovery area to return to earth; range safety observer, to make sure the vehicle stays within specified limits during launch; flight director, who coordinates all operations; network status monitor, whose main job is to keep the members of the tracking team coordinated; and a missile telemetry monitor, checking telemetry channels.

Behind these watchers comes a third line of observers: a U.S. Navy observer, a U.S. Air Force observer, and the NASA operations director. On the right side of the room, facing plot boards alongside the big map, two more key men sit: the flight dynamics officer, who checks to see that the flight is proceeding along a previously calculated path, and the retrofire controller, who can fire jets to slow the capsule up on its reentry.

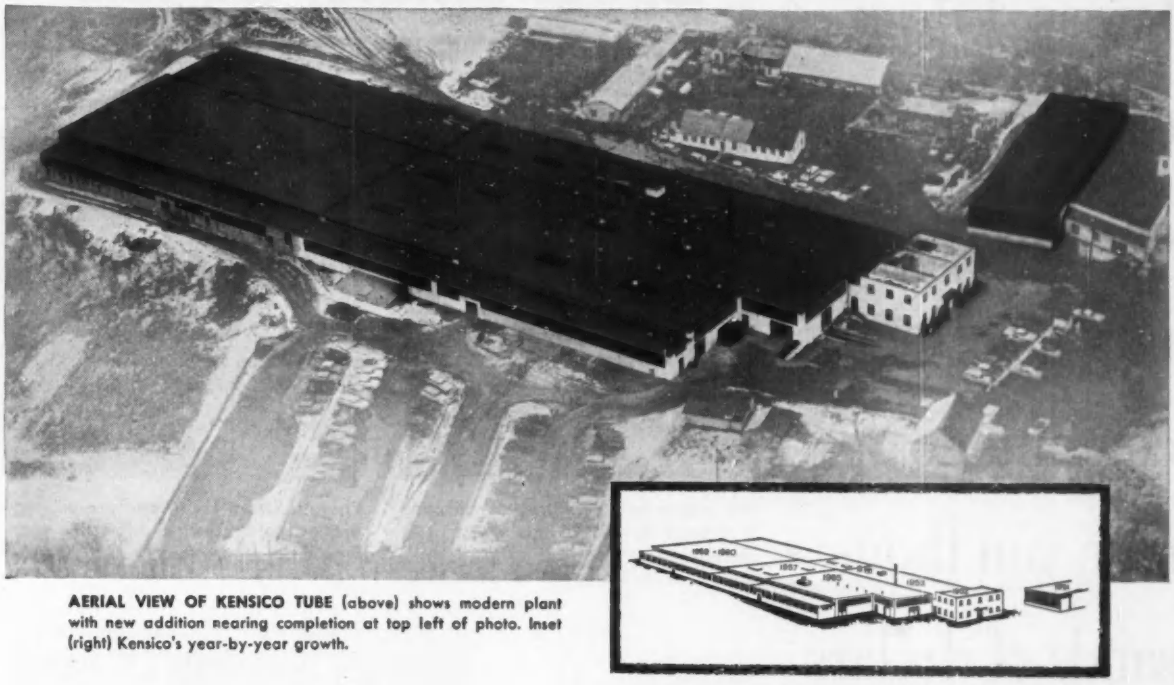
In addition to the big wall displays, the control room has a data entry console into which teletype messages and reports can be inserted for display on an individual monitor's console.

• **Around the world**—The wall map shows the range of ground stations' tracking radars and capsule communications system. By looking at the map an observer will be able to tell when each remote station has established contact with the capsule. Digital displays along the top of the map will show Greenwich mean time, countdown time, time to retrofire (for reentry), elapsed time, and the number of orbits that have been made. Servo-controlled X-Y indicators will show the actual position of the capsule and indicate the impact point.

The Operations Summary Display will have real illuminated status displays, consisting of lamps behind alphanumeric stencils. The trend charts will be manually plotted to show rates of usage of materials such as fuel and oxygen. **—Kemp Anderson**
McGraw-Hill News

←CIRCLE 30 ON READER SERVICE CARD

SET FOR THE SOARING SIXTIES



AERIAL VIEW OF KENSICO TUBE (above) shows modern plant with new addition nearing completion at top left of photo. Inset (right) Kensico's year-by-year growth.

PACE-SETTER during a period of phenomenal growth in northern Westchester County, N. Y. Kensico Tube is Mt. Kisco's largest manufacturing business. Products include: hard and soft copper water tube; copper air conditioning, refrigeration and instrumentation tube; and copper tubing for propane gas lines, heat exchangers, automotive and industrial applications. Now, after more than a decade of corporate growth and expansion of production and marketing facilities, Kensico is set to meet the challenge of the SOARING SIXTIES.

IN 1950, CONSTRUCTION of first new building was started. Kensico had been chartered under N. Y. State Law in 1945. Under present management since 1948. Until 1951, company was located in an old cider mill which it leased (floor space 8500 sq. ft.).

TODAY, AFTER PUTTING UP 4 MORE ADDITIONS, Kensico has more than 60,000 square feet of modern fireproof plant and office space.

BY SPRING, 1960, Kensico expects to complete a new 40,000 square foot addition to the plant. Total plant and office space will then exceed 100,000 square feet.

PRODUCTION HAS INCREASED with each addition since 1950. It will be still further increased in both capacity and range of sizes by the new 1960 addition.

IN THE TEN YEAR PERIOD, 1950-1960, Kensico has had a 7-fold growth in gross sales.

EFFECTIVE FEBRUARY 1st 1960, Kensico Tube Company Incorporated, Mt. Kisco, N. Y., merged with Robinson Technical Products, Inc., Teterboro, N. J. Robinson also has other corporate facilities at Hingham, Mass., and Santa Monica, California. The merger strengthens Kensico's position in engineering and metallurgy and places new technological know-how and experience at the disposal of Kensico's customers. Kensico's new name is KENSICO TUBE COMPANY DIVISION — ROBINSON TECHNICAL PRODUCTS, INC.

Kensico Tube
COMPANY DIVISION
Robinson Technical Products, Inc.

MOUNT KISCO, NEW YORK

Kensico Products are also Available Through Warehouse Distributors and Sales Representatives in Cambridge, Mass.; Middlebury, Conn.; Buffalo, N. Y.; Lindenhurst, N. Y.; Goshen, N. Y.; Roselle, N. J.; Philadelphia, Pa.; Flourtown, Pa.; Pittsburgh, Pa.; Cleveland, Ohio; Detroit, Mich.; Evanston, Ill.; St. Louis, Mo.; Milwaukee, Wisc.; Durham, N. C.; Berwyn, Ill.; Ft. Lauderdale, Fla.; St. Petersburg, Fla.

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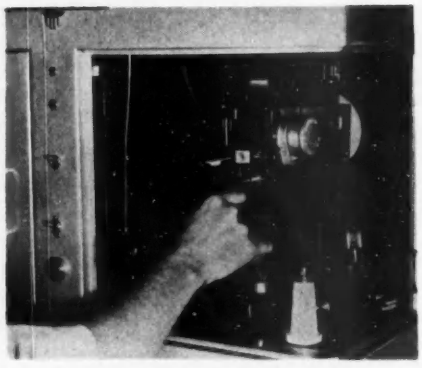
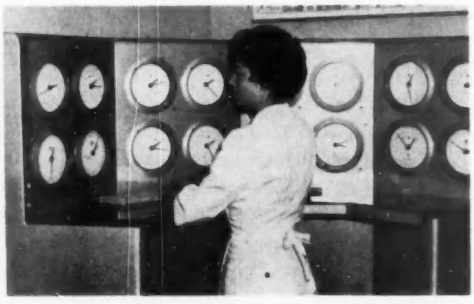
Spectrometer Directs Maintenance Program

Hot engine oil from truck crankcase is shipped to central lab where it is placed in . . .



Photospectrometer to analyze oil, separating spectra with a diffraction grating. One minute later . . .



Results are displayed on 16 panels, one for each of 16 substances. Dials read parts per million of substances found in oil.

OAKLAND, CALIF.—

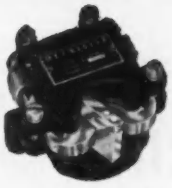
A photospectrometer put to work in a trucking company's laboratory is saving $40,000 a year by cutting bills for lubricating oil and filters and reducing maintenance labor. And substantially bigger savings have started to accrue. Pacific Intermountain Express's new maintenance program has been so successful that it may change the trucking industry's whole approach to engine maintenance.

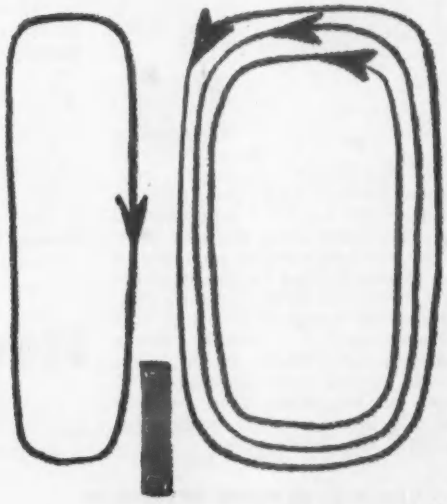
PI Express now dictates all its engine maintenance from a special petroleum research laboratory at Emeryville, Calif., although personnel of the laboratory never actually see any of the company's 869 vehicles which operate between 40 terminals from Chicago to the West Coast. Still, anything from a crankshaft replacement to a complete teardown may be ordered from Emeryville, solely on the basis of scientific information gleaned from an analysis of engine oil.

The new concept is the brainchild of Charles Jackson who brought his ideas of preventative maintenance to the trucking company in 1958. Jackson pointed out that railroads used engine oil to determine maintenance of diesel locomotives so truckers ought to be able to do the same thing.

The theory behind Jackson's idea is simple: since an engine consists of parts made of different metals and alloys, and since these materials tend to wear off into engine oil during operation, an engineer can determine the degree of wear by analyzing the engine oil. Two problems had to be solved: first, provide an instrument that can deliver qualitative and quantitative analysis of particles fast, and second, determine how much of a metallic element in the oil constitutes a problem.

• **Enter the photospectrometer**— The equipment answer was found to

Metrisite... is the only  device available today that provides a near-perfect combination of ideal transducer characteristics. The unusual properties of this remarkable new motion-sensing development are: extreme resolution... easily measures one ten-millionth of an inch; minute operating force... absolute minimum bearing friction; negligible reactive force... a fraction of a milligram; true linearity...a proven accuracy of 1/10%; high electrical output...up to 100 volts without amplification; wide range of shapes and sizes... from sub-miniature on up; exceptional ruggedness...can meet military shock and vibration tests. Now, many of the obstacles that have plagued control technology can be eliminated. Write for Metrisite details.



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DIVISION OF CLEVITE CORPORATION
37TH AND PERKINS CLEVELAND 14, OHIO

CIRCLE 33 ON READER SERVICE CARD

D-C AMPLIFIER EVALUATION *number 2 in a series*

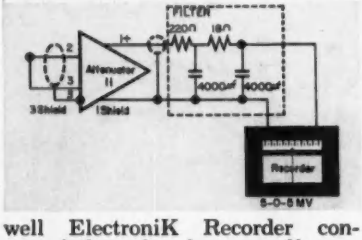
ZERO DRIFT

Accuracy in d-c amplifiers is fundamentally dependent on zero drift. This error, defined as any zero offset appearing at the amplifier output but not present in the input, is indistinguishable from the d-c input signal, and varies more or less sporadically with time and/or ambient temperature. Elimination of zero drift is a prime d-c amplifier design objective.

Evaluation of the amplifier zero drift characteristic is quite simple, but elimination of the effect is not. For example, any direct-coupled stage of amplification will drift due to the inability of circuit operating levels to remain constant. The use of inverse feedback does not have any beneficial effect on drift. The best generally accepted method of drift elimination is to make all amplification drift-free through a-c coupling, and converting the incoming d-c to a-c directly by means of a low-level modulator, such as a chopper or magnetic converter. After amplification, the a-c is demodulated into d-c which may be further amplified at high levels without appreciable zero error. This system is used in both the so-called chopper amplifier (where the band pass is limited by the chopper frequency) and the chopper-stabilized amplifier (where the chopper amplifier is combined with a wide band amplifier to give frequency responses well beyond the chopper excitation frequency).

Testing Amplifiers for Zero Drift

Zero drift is measured at the amplifier output with a strip chart potentiometer such as the Honeywell ElectroniK Recorder connected through a low pass filter as shown. The amplifier input should be shorted. Equivalent input drift is the absolute amount recorded at the output divided by the amplifier gain measured under known conditions of temperature and line voltage, and, if necessary, for a specified time. There do not seem to be agreed-upon definitions of short or long-term time periods. For further details, write for Bulletin BE AN122.



Zero Drift Less Than 0.002 Per Cent at 10 mv

The AccuData II, Honeywell's all-transistor, wide-band, differential input, chopper-stabliized, d-c amplifier, has the lowest drift of any amplifier in its field — something less than 0.5 microvolts at reasonably constant ambient temperature, or less than 2 μv with a 10°F change in ambient. The effect of line voltage never exceeds 1μv for a ±10% change, hence, under conditions most frequently advertised for amplifiers, its zero error on a 10mv input range would be less than 0.002%

The AccuData II has single-ended as well as differential input ranges, input impedance of 2 megohms differential (20 megohms single-ended), and power output sufficient to drive the highest frequency galvanometer oscillograph to its maximum deflection. In addition to excellent drift characteristics, the AccuData II offers exceptional linearity, very low noise, and frequency response to 20kc. Write for Bulletin BS DISA-1000 to Minneapolis-Honeywell. Boston Division, Dept. 34, 40 Life Street, Boston 35, Mass.

Honeywell

First in Control

SINCE 1885

WHAT'S NEW

be a Baird-Atomic photospectrometer which was specially adapted to the problem. Its operation: a small sample of crankcase oil is subjected to a high voltage spark which causes each element to emit a characteristic wavelength. Then, a diffraction grating breaks up the emitted light into a spectrum which is converted to electrical energy to activate a bank of direct reading gages.

What turned out to be tough was establishing standards for critical readings. Over a period of several months, Jackson and his staff ran 46 engines to death, making frequent tests to develop correlations between engine wear, age, and particles in the oil.

Here's how the PI Express maintenance program now operates. Each terminal sends one pint of hot crankcase oil to Emeryville from each truck every time the vehicle travels 7,500 miles. The laboratory runs the oil through the photospectrometer, then tests viscosity, acidity, and water and fuel contamination conventionally.

Jackson's laboratory staff keeps a card dossier on each engine, showing the results of each periodic analysis. By comparing these cards with his standards, Jackson can tell if an engine is wearing evenly and "on schedule". If too much of an element shows up in the oil analysis, he sends an order for appropriate maintenance.

• **The payoff**—Just how well the method is paying off can be seen by examining some operation statistics. In 1958 PI Express' road failures averaged one in 51,000 miles. Last year, road failures decreased to one in 69,000 miles. And so far this year failure rate is even lower.

Before the laboratory started checking oil, the maintenance program dictated an oil change every 15,000 miles. Now mileage between changes averages 22,500, increasing the life of oil 50 percent.

But the greatest savings are still ahead. They will accrue from the stretching of mileage between engine overhauls. Previously, regardless of condition, PI Express rebuilt engines completely every 250,000 miles, or about once in two years. The company expects to stretch this safely to every 400,000 miles.

• **Next, gear boxes**—Next step in engineer Jackson's plan is to extend his analysis method to transmission and differential preventative maintenance. The objective: to end over-maintenance and under-maintenance.

—Donald Winston
McGraw-Hill News

WORKING PARTNERS

RCA 501 — SOUNDCRAFT INSTRUMENTATION TAPES

R-96

Big business depends more and more upon electronic data processing. For many corporations, the heart of their data reduction and storage operation will be the new RCA 501 Computer System. The crucial testing period of this new computer called for the most reliable of instrumentation tapes . . . Soundcraft. And, Soundcraft Tape proved to be the perfect working partner—not only in the testing, but afterward, in continuous working use.

In short, experience has proven that Soundcraft works best on leading computer systems, like the RCA 501. Let precision-made, trouble-free, error-free Soundcraft Instrumentation Tapes go to work for you. *Complete literature on request.*

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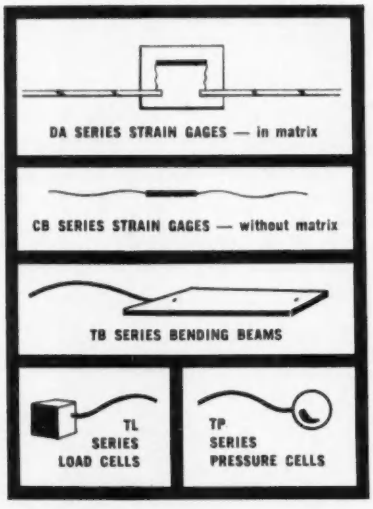
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More New Computers:

RCA's New Computers Raise Curtain on Three C's

NEW YORK—John L. Burns, president of Radio Corporation of America, is shaping a new image for the company. For it he has a motto: CCC—control, computation, and communication. When RCA unveiled two new computers (the medium sized 301 and the large sized 601) last month, Burns had a first-rate opportunity to clarify his concept of how computers—the middle C—will link with the other two C's.

To illustrate his point, Burns offered railway freight car traffic control as an example, a case which might use three separate computers. As an input he envisioned optical (probably human eye) identification of the freight cars. To identify a car without doing anything to it, Burns envisioned a code for each car: three letters to indicate the owner railroad and six digits to identify the car.

Once identification was complete, RCA's digital data link DaSpan would link the remote identifying station with a yard computer (like the RCA 301) and with the office of the yard superintendent. The medium sized data processing computer would then set up switching schedules for the yard and optimize car routing within the limits of fixed freight schedules. Another computer (of the process control type, like RCA's 110) might control the classification yard from instructions issued by the data processing machine.

Meanwhile a centralized data processing system (using a machine like the RCA 601) would keep track of car movements, answer queries from shippers, read out car availability data, and account the per diem charges on cars owned by other railroads.

• **Details on new machines**—RCA's two new machines help fill out a line which already has the RCA 501 data processor and the RCA 110 control computer. The new 301 is transistorized, rents for up to $9,000 per month. The 601, also transistorized, rents for up to $20,000 per month.

Main units of the 301 system include a modularized basic processor, which serves as the computer's control unit; a disc file of the "juke box" memory type, holding 128 discs with magnetic recordings on both sides for a capacity of 4.5 million data characters; tape stations, up to 12 newly-developed magnetic tape units capable of storing up to 4 million data characters; and a high speed printer that prints 72,000 characters per min.

The 601 system includes a computer, tape stations, an online printer, and a card reader-punch—a transistorized combination unit which reads cards at a rate of 600 per min and punches cards at a 100 per min rate.

—W. E. Vannah

IBM Wins the Numbers Game

NEW YORK—Taunted by a recent Radio Corporation of America announcement—that RCA had sold over 50 of its 501 electronic computer systems and had installed more solid state machines than any other manufacturer—an angry IBM retaliated with some eye-opening statistics of its own. President Thomas J. Watson, Jr., in a precedent-making speech (IBM has not recently released numbers of sales), told the company's annual meeting that IBM has already sold over 2,800 of the new 1401 data processing systems, a computer just announced in 1959 and selling for from $150,000 to $250,000 per installation.

For good measure, President Watson informed stockholders that IBM would ship over 1,100 solid state machines—small, medium, and large sized—in the next 12 months.

But this startling news was only a teaser; IBM had even more startling disclosures. First off, the company will market to industrial users STRETCH, a special giant sized computer developed primarily for the Atomic Energy Commission. With a price tag of over $10 million, STRETCH can perform over 1 million operations a second. It is the most powerful computer on the American scene.

Developed for use with STRETCH, said Watson, adding frosting to the IBM cake, is a revolutionary new tape handling system—called TRACTOR—that can write-in or write-out 1.5 million characters per sec—a super-giant-step improvement over IBM's

Second in a series of check lists on Annin features

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MINIMUM PARTS and simplicity of construction in Pneumatic Position Unit.

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WIDE CHOICE of special body gasketing for all applications within temperature-pressure limitations of any valve.

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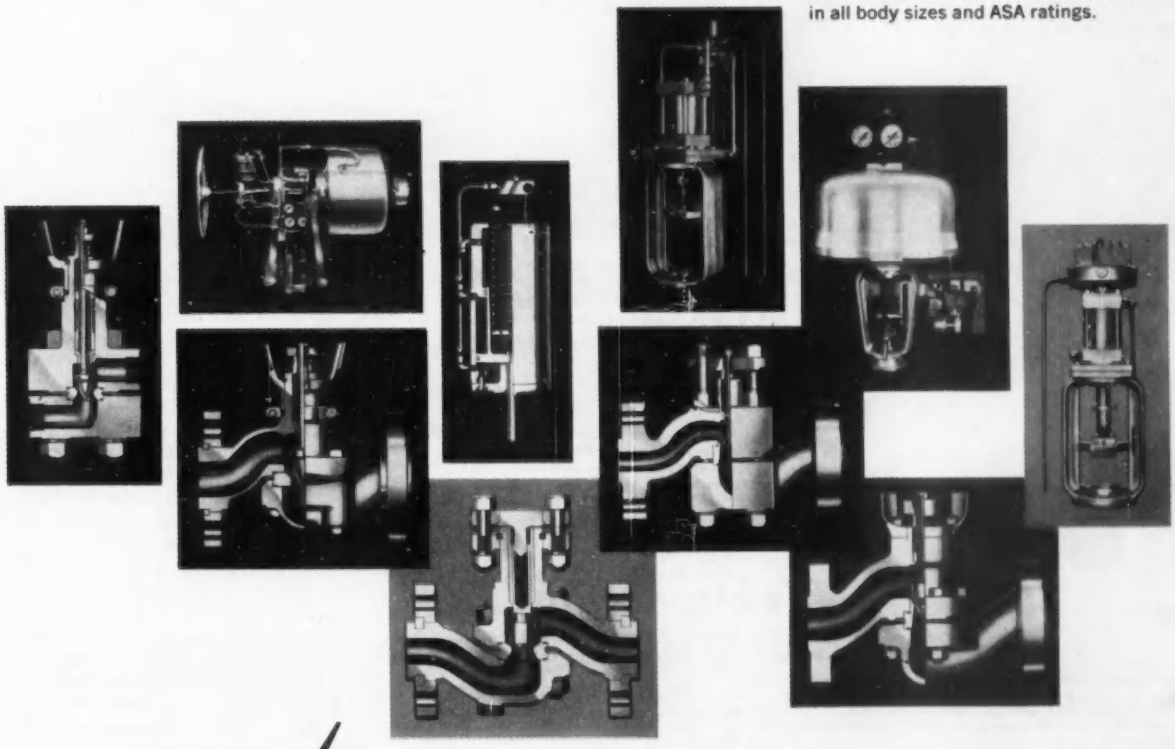
SPLIT BODY CHECK VALVE available in all body sizes and ASA ratings.



Annin **VALVES**

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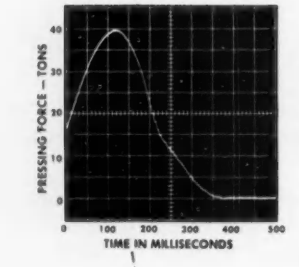
CIRCLE 37 ON READER SERVICE CARD

USING STRAIN GAGES?

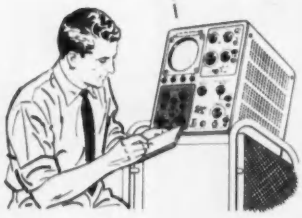


Information from strain gages and many resistive, capacitive, and inductive transducers can be displayed on the face of a cathode-ray tube . . . with the Type Q Plug-In Unit and any Tektronix Plug-In Oscilloscope.

You get a detailed picture of this information plotted against time, from which accurate measurements can be made with ease. The illustration, a plot of a press stroke, is an example of a quality-control application.

It's quite likely that your lab is already equipped with one or more Tektronix Plug-In Oscilloscopes. If so, the only additional expenditure will be the price of a Tektronix Type Q Plug-In Unit—$300 f.o.b. factory.

The Type Q Unit plugs directly into these oscilloscopes: Tektronix Types 531, 531A, 532, 533, 535, 535A, 536 (for X-Y plots), 541, 541A, 543, 545, 545A, 551 and 555 (dual beam), and all their rack-mounting versions. It can also be used in the Type 81 Plug-In Adapter with both the Type 581 and Type 585, and in the Tektronix 127 Preamplifier Power Supply with any standard laboratory oscilloscope and many other readout devices.



Maximum sensitivity of the Type Q is 10 microstrain/division when used with a single strain gage with a gage factor of about 2. Frequency range is dc to 6 kc (3 db down), with excellent transient response.

For complete information, or assistance with strain-gage and other transducer readout problems, please call your Tektronix Field Engineer.

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TEKTRONIX ENGINEERING REPRESENTATIVES: Hawthorne Electronics; Portland, Oregon • Seattle, Washington. Tektronix is represented in twenty overseas countries by qualified engineering organizations.
In Europe please write Tektronix Inc., Victoria, Ave., St. Sampsons, Guernsey C.I., for the address of the Tektronix Representative in your country.

WHAT'S NEW

conventional tape handling unit which dawdles along at a slow-poke (by comparison) rate of 62,500 characters per sec. Arranged in special racks which are automatically pulled in and out by the computer, the total tape handling capability of STRETCH is 60 billion characters. –L. H. Y.

RCA, PANAM Split On Missile Range

CAPE CANAVERAL—

The quality of missile tracking that has been synonomous with the Air Force's Atlantic Missile Range may face a serious test in the coming weeks because of the loss of key tracking experts. Pan American World Airways, which operates the range for USAF, has dropped RCA Service Co. as subcontractor for range engineering at the Florida missile testing facility.

In an arrangement described as "for the mutual convenience of RCA, Pan American, and the Air Force", RCA is transferring 250 technical men of its highly rated Range Engineering section to PAA. But here's the snafu: many of the highly skilled RCA personnel are reported as reluctant to tie up with PANAM.

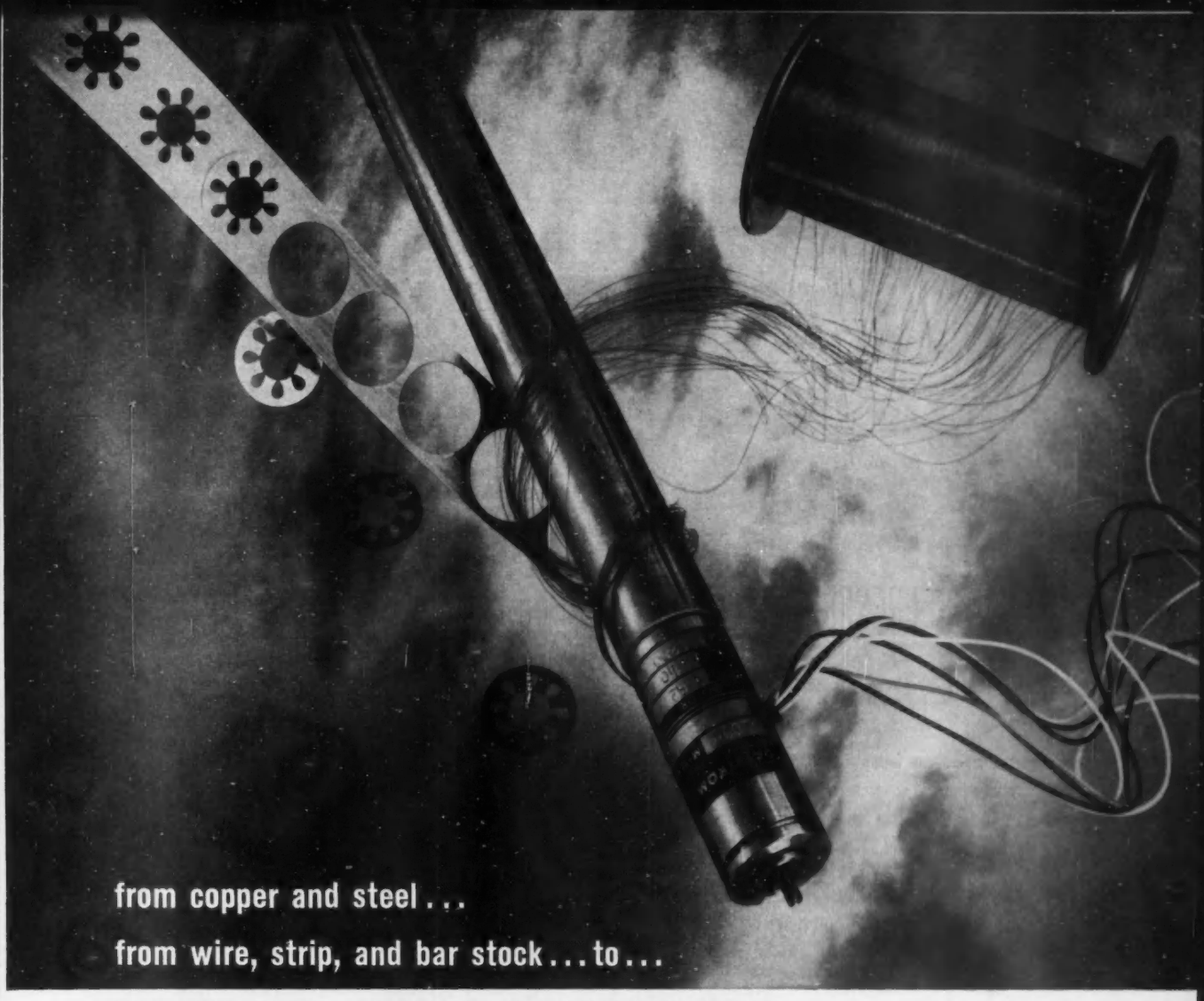
The men involved in the transfer have been interviewed by PANAM recruiting officials, but many of them told CtE that they will not accept positions with the new engineering unit. Reason: the RCA men fear they will lose the prestige built up by association with RCA by joining PANAM, which is not primarily an electronic engineering outfit.

PANAM has been running a series of technical recruiting ads recently, said by some observers to be an attempt to promote the engineering image of the company. It is not known how many engineers were hired from the ads.

The actual transfer of range engineering duties will take place in July when RCA's contract with PANAM expires. The transfer of personnel will be phased over a short period.

Range Engineering is the section of AMR which specifies and purchases equipment to track firings from the Cape and develops the sophisticated tracking systems. CtE has learned that RCA, which was in the position of specifying the equipment needed for a new tracking requirement, had also submitted a bid to supply the equipment. PANAM rejected the bid, thus broadening the gap between them.

–Douglas Dederer
McGraw-Hill News



COMPLETE SERVO ASSEMBLIES

We are not an assembly station. We are a manufacturer!

Steel and copper come into our factory. Housings are turned and gears are hobbed from the solid stock. Laminations are stamped from strip steel. Copper is wound right off the reel.

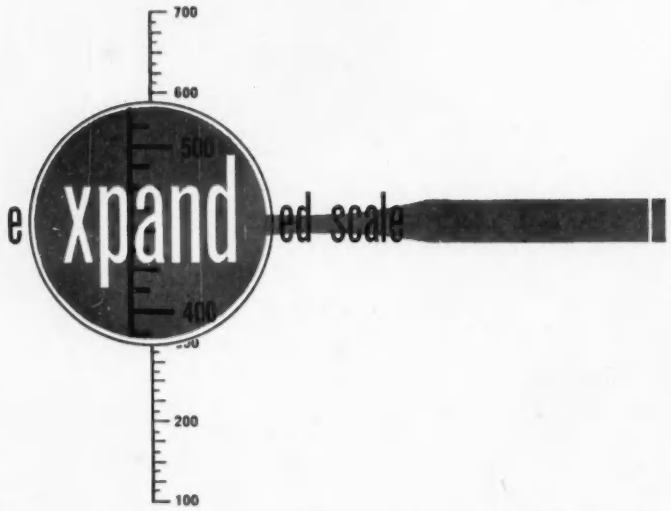
Every operation between raw stock and servo assembly is performed in our own plant, under our own supervision. And because we exercise this complete control over manufacture, we can honestly vouch for the quality and reliability of every motor, generator, synchro, and gear train carrying our name.

Undivided responsibility isn't a new idea by any means, but it is increasingly difficult to find in this age of overspecialization. If you'd care to sample the benefits of this integrated approach, why not call on us now?

SERVO ASSEMBLY – Type 9 motor generator driving two Type 11 CT synchros through a slip clutch and a gear train having ratio of 1500 to 1.

DAYSTROM, INCORPORATED
TRANSICOIL DIVISION
WORCESTER • MONTGOMERY COUNTY • PENNSYLVANIA

CIRCLE 39 ON READER SERVICE CARD



DC PRESSURE TRANSDUCER

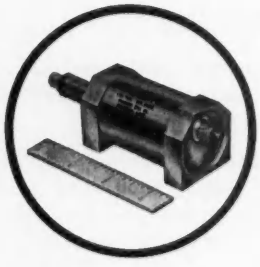
Interested mostly in the high end of a transducer's rated range?

Wiancko's P2-1253 concentrates on specific portions of range; e.g., 475 to 550 psi. It provides full 5 volts dc output for this portion of the range rather than dissipating the output in areas of no interest, and it increases the accuracy proportionally. This unique application is made possible by the inherent advantages of the Wiancko sensing element.

The high output permits direct coupling to airborne telemetry systems without amplification. In addition, this transducer offers exceptional resistance to acceleration and vibration, no friction effects, constant output impedance and continuous resolution.

COMPARE THESE SPECIFICATIONS

Operating range	475 to 550 psi (others available)
Output voltage	0 v to 5 v dc (28 v dc input)
Accuracy:	
Linearity & Hysteresis	Better than 0.15% of reading
Temperature effects (0 to 165 F)	Better than 0.5% of reading
Vibration	30 g, 0 to 2000 cps



Further information contained in EDS 699 & Product Bulletin 108A

WIANCKO
ENGINEERING COMPANY

255 North Halstead Avenue • Pasadena, California

Precision with lasting reliability

WHAT'S NEW

Standard Takes Three Giant Steps in Computing-Control

FRENCH LICK, IND.—Standard Oil Co. (Indiana) last month revealed some exciting details of its first venture into computing-control—for an installation at the No. 12 pipe still at its Whiting refinery.

CtE reported Standard's investigations of computer control as far back as October '59 (Newsbreaks, p. 23) and noted the company's decision to adopt closed-loop control just last month (Newsbreaks, p. 19). New disclosures represent the first specific data available.

The No. 12 pipe still is a 140,000-bpd crude unit, the newest (one year old) and biggest in the country. The computer control for the unit will be the largest and most extensive in the oil industry. At the start, which is understood to be sometime during the summer, SOIND will use an open-loop system, but will probably switch to closed loop before December.

According to Dr. Robert B. Jacobs, director of engineering research, Standard is still "open minded about open loop vs closed loop".

Standard has not identified the computer to be used, but it is probably an IBM 704 installed at Whiting earlier this year. After the switch to the closed-loop system, other computers could be used.

The computer will control all phases of the process to obtain greater throughput and a cleaner cut. Manpower reduction is not a goal. CtE has learned that Standard is aiming for a saving of $200,000 to $500,000 a year.

There will be 10 control variables and several hundred inputs, as far as CtE can estimate. The computer will change set points of the already highly instrumented still. Optimizing will take place hourly or maybe half-hourly. Scanning rate: several times a minute.

Big boost to Standard's computing-control is its previous development of important instruments: for instance, an ASTM boiling point analyzer which can feed end point analysis directly to the computer.

Based on experience gained with the No. 12 still, Standard will probably install computer control on a crude distillation unit at its American Oil Co. affiliate's Texas City, Tex., refinery. SOIND is also working on computer control of another Whiting refinery unit.

—Stewart Ramsey
McGraw-Hill News

A *Versatile* PULSE SOURCE FOR TRANSISTOR TESTING . . .

Turn-On Time, Rise Time, Fall Time . . . three of the more important transistor characteristics measured at Philco's Lansdale Division with the aid of a General Radio 1391-B Pulse, Sweep, and Time-Delay Generator — a *complete* pulse system. To make repetitive measurements of the various transistor types faster and with minimum resetting of their test console, Lansdale's engineers have designed a circuit jig (shown on the work table) for each transistor type. Type 1219-A Pulse Amplifier (shown under Type 1391-B) provides additional pulse amplification.

Features of the Pulse Generator that are particularly useful in Lansdale's quality control program include: excellent rise and decay time characteristics (0.015 μsec); the extremely wide range of pulse durations; lack of duty ratio restrictions; variable output impedance; the ability to put the pulse's zero reference level above ground level; and in general, the wide variety of useful waveforms that the generator can produce.

Photo Courtesy of Philco Corporation, Lansdale Division

. . . A *Versatile* PULSE SOURCE FOR MANY OTHER MEASUREMENTS

Echo Ranging, Telemetering, Computer Research, Television, Radio Navigation

- ★ Rise and Decay Times Better Than 0.015 μsec
- ★ Pulse Durations From 0.025 μsec to 1.1 sec
- ★ Time Delays From 1 μsec to 1.1 sec

Type 1391-B Pulse, Sweep, and Time-Delay Generator . . . $2025

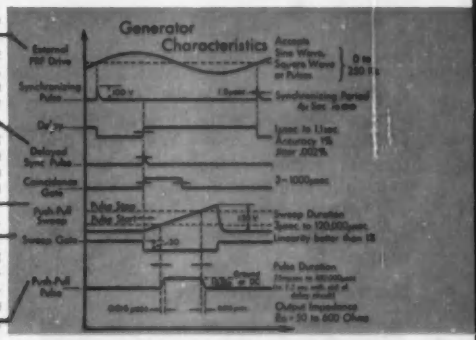
Direct synchronizing pulse timed by the input signal.

Delayed synchronizing pulse accurately adjustable in time by delay generator. Built-in coincidence circuit for timing the delayed synchronizing pulse by externally generated pulses fed into the instrument.

Push-pull sawtooth voltage of sufficient amplitude to be applied to the deflection plates of oscilloscope for examining the generator's output pulses, or for use in driving auxiliary equipment.

Push-pull gating pulses with same duration as the sweep.

Positive or negative pulses with excellent shape characteristics, continuously adjustable in duration, amplitude, impedance level, and delay with respect to (a) the direct sync pulse and (b) the sweep.



Write For Complete Information

GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS

our 45th year in Electronics

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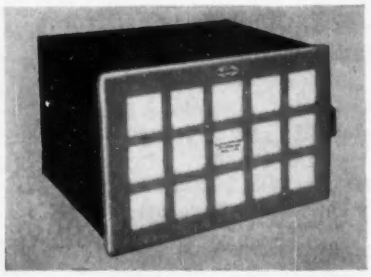
CIRCLE 41 ON READER SERVICE CARD

bmc
CANCO
RCA
NASA
Judging by the Company We Keep...
Electro-Mech

. . . "the Company We Keep" are fastidious in their purchases of Custom Control Systems. They demand the best, the most flexible and the most dependable alarm systems for their process control centers.

The Electro-Mech "UNIVERSALARM" annunciator has gained a good deal of attention by instrument engineers in the major industrial companies. These are men who *know the difference*, a discerning group of specialists who understand and insist upon the most advanced and most capable instrumentation available.



ELECTRO-MECH "UNIVERSALARM" ANNUNCIATOR

If you are interested in the finest of annunciation equipment, we suggest that you join "the Company We Keep" and request further information on this unusual alarm system, which has *built-in* ability to respond to changing plant requirements without radical circuit revision.

Electro-Mech Corp., Norwood, N. J.

Electro-Mech

General Controls Blows Out Its Thirtieth Candle

From a start selling combustion controls door to door during the Depression, the Ray brothers have built a diversified $40 million a year company; six domestic, three foreign plants have replaced a single Oakland, Calif., loft.

President and chief engineer of General Controls, William A. Ray, has approximately 300 patents for the company to his credit. His developments are prime reasons for the firm's position.

GLENDALE, CALIF.— Thirty years ago even mousetrap makers had a hard time getting customers to beat a path to their corporate doors, and a tiny combustion controls firm in Oakland, Calif., was having no better success. Setting up shop in a roomy loft on $10,000 borrowed from their father, the Ray brothers' General Controls Co. cut its company teeth on the Depression years.

When business became too slow, the aggressive Ray brothers would load the company truck with their small line of combustion controls and sell them from door to door to plants in the neighboring area. Sales the first year were a modest $2,000. GC grossed $40 million last year, should reach well over that in 1960.

GC's marketing techniques have mellowed during the intervening years, but the Ray brothers are as aggressive as ever. Bill Ray, the oldest at 55, is the company's president and chief engineer; Al Ray is now executive vice-president. Younger brothers Jack and Dick, who joined the firm in the late thirties, are now v-p's for sales and manufacturing, respectively.

• **Self-generating sales**—General Controls' first real break came in the late thirties when Bill Ray developed the B-60, the industry's first reliable self-generating heating control. The device generates a millivolt signal from a pilot flame for remote operation of a main line gas valve. The B-60 chalked up the fledgling company's first big sales gains, put the outfit in the heating controls business.

World War II found GC deep in the war effort. A pioneer in the development of solenoid drives, the firm found widespread application in the aircraft field for its hi-g solenoid line. General Controls was one of the first companies to develop lightweight solenoids with low power requirements; the company's units were used on a variety of wartime aircraft.

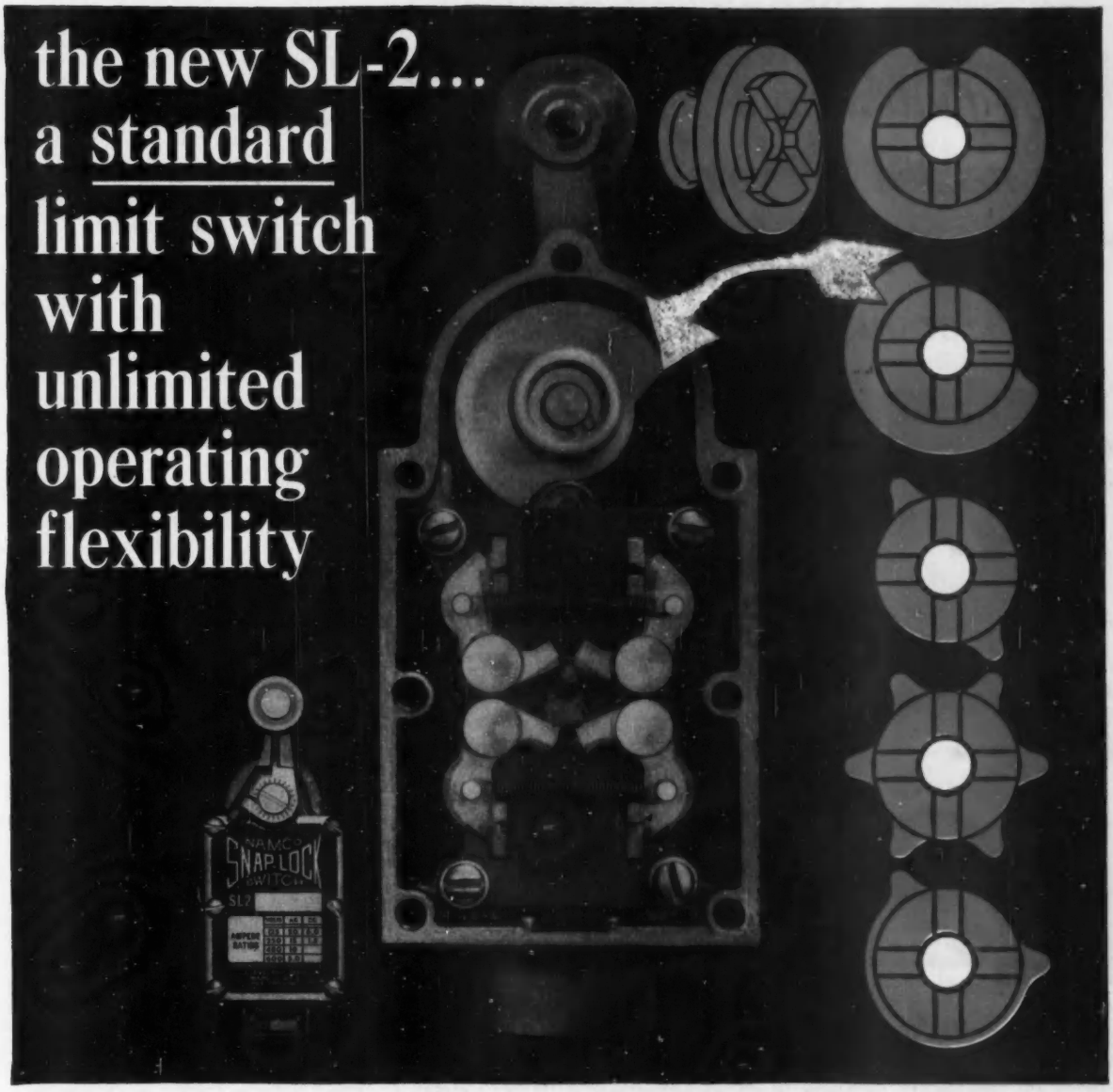
But throughout the thirties and forties General Controls remained a small company, its growth steady but unspectacular. The Ray brothers had moved conservatively, attempting to finance growth from company earnings rather than through public financing.

• **Acquired growth** — In 1950, though, the company seemed to hit its stride. That year sales exceeded $13 million—almost double 1949's. Since '50 GC has substantially enlarged its product line and marketing base. A sizeable portion of this expansion has been the result of an active acquisition program.

Beginning in 1951 General acquired Grayson-Greenamyer (maker of appliance controls), in 1955 Perfex Co. (oil burner controls), in 1957 Production Instrument Co. (counters, precision switches), in 1958 Hammel-Dahl Co. (control valves), in 1959 Foster Engineering Co. (steam specialty devices), and in May of this year Trimount Instrument Co. (manometers).

Most of GC's products are manufactured in six domestic plants and

the new SL-2... a standard limit switch with unlimited operating flexibility



Tailor limit switch performance to your specific job with NAMCO'S *standard* SL-2. This "machine life" limit switch features a standard cam blank which can be cut into a wide variety of configurations to meet any application. These interchangeable cams provide positive control of contact sequence; let you match switch operation to your specific job. Ruggedly built, oil-tight and moisture-proof, the SL-2 provides dependable, accurate performance that meets your most precise requirements.

Now available for low-current, high-shock, excessive-vibration applications...the SLS-2... with full-wiping, self-cleaning sliding contacts that insure "everytime" operation under conditions that spell machine downtime for other limit switches.

Get all the details on how the NAMCO SL-2 line eliminates limit switching problems for good. Write for Bulletin EC-SL260, or contact one of our representatives. You'll find them in all principal cities.

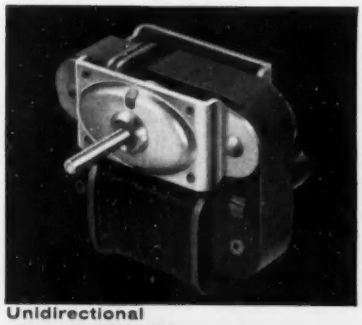
National Acme

THE NATIONAL ACME COMPANY
165 E. 131st STREET
CLEVELAND 8, OHIO

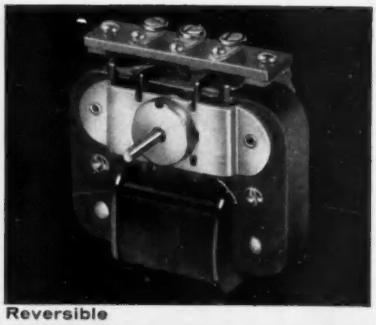
Sales Offices: Newark 2, N. J., Chicago 6, Ill., Detroit 27, Mich.

CIRCLE 43 ON READER SERVICE CARD 43

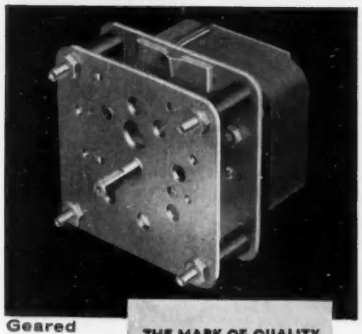
Which of these Barber-Colman high-quality, low-cost motors are needed for your applications . . . unidirectional, reversible, synchronous, or geared?



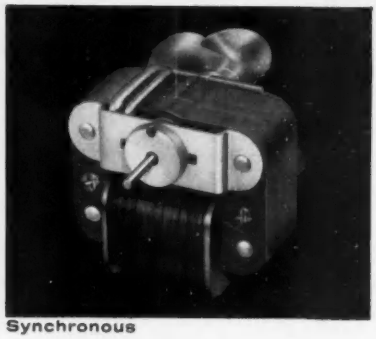
Unidirectional



Reversible



Geared



Synchronous

THE MARK OF QUALITY

BARBER COLMAN

a-c small motors

For longest life and finer service per dollar invested, put Barber-Colman motors into your products. High-quality construction throughout eliminates bothersome, costly maintenance . . . adds to *your* reputation as a builder of quality equipment. Various types and models for use in appliances, vending machines, projection equipment, office machines, toys, servo-mechanisms, remote switching and positioning, recording instruments, and similar applications. And your cost for these precision-made motors is surprisingly low.

LOW COST

HIGH STARTING TORQUE

QUIET OPERATION

LONG-LIFE LUBRICATION

POROUS BRONZE OR BALL BEARINGS

PRECISION-HOBBED GEARS

QUALITY GUARANTEED

WRITE FOR NEW QUICK REFERENCE FILE on the complete line of Barber-Colman a-c small motors: Unidirectional, reversible, synchronous. Up to 1/20 hp. With or without reduction gearing . . . open or enclosed types. Stator and rotor sets also available. Free engineering service.

BARBER-COLMAN COMPANY

Dept. F, 1248 Rock Street, Rockford, Illinois

marketed through 44 branch offices in the U. S., Canada, and Western Europe. But along with other control makers (CtE, Oct. '59, p. 54), General Controls has had its eye on the potentially lucrative foreign market. Convinced that most controls can no longer be exported competitively, GC has made a strong bid during the last 18 months for a share of the European controls market.

Its first move in that direction came in Jan. 1959 when it established a German subsidiary, General Controls GmbH, in Dusseldorf, West Germany. Initially acting as a sales and distribution center, by year's end it had begun turning out a number of the parent company's products.

Six months later the company organized General Controls International S.A. at Fribourg, Switzerland, as sales and marketing headquarters for continental Europe. In July 1959 General Controls Ltd. was set up at Basildon, Essex, England, to provide production of a number of company products in pound sterling areas.

• **Still to show**—To date, General Controls says, the European operations haven't materially affected company sales and earnings, but it believes that its vigorous entry into the European market will substantially augment the firm's income and stability by the middle or late sixties. In addition to the European activities, a Canadian division at Guelph, Ontario, was enlarged this year with the goal of expanding in industrial controls.

Expansion of the industrial segment of its sales is an important aim of the company's management. In 1950 sales were principally for heating and air conditioning controls. In the mid-fifties, however, GC began a strong bid for industrial controls business.

By 1959 the changing pattern of sales showed that heating, air conditioning, and refrigeration controls still made up the biggest piece of the business at 45 percent. Home appliance applications accounted for 15 percent and aircraft/electronics goods, 10 percent. But the industrial line had grown to 30 percent.

• **Prime mover**—Chief driving force behind General Control's growth is Bill Ray. Remarkably inventive, the senior Ray has approximately 300 patents and patent improvements registered in his name. Before the company's rapid growth by the acquisition route, 99 percent of the firm's patents could be attributed to Ray efforts. Currently approximately 50-60 percent of new GC patents originate with Ray.

His preoccupation with development has left Ray open to charges that he spreads himself too thin, dividing his time between engineering and managing. But his defense is easy: it's no secret that the company's 30-year growth is chiefly the result of Ray's engineering talents.

Latest of Ray's personal developments is a manual reset thermoelectric holding magnet. Inputs from two separate thermoelectric or electric sources operate a magnet; failure of either source to provide current automatically releases the single magnet structure. General Controls is currently investigating commercial applications of the device.

• **Systems plunge**—Recently General Controls undertook a short-lived venture into the systems field, establishing an Electronic Systems Div. early in 1958. Product nucleus of the division was a central air data computer and navigation and flight control subsystems. Late in 1959 General sold the division to Litton Industries, even though a few months prior to the sale the group had been awarded a sizeable production contract for the air data computer for use in the West German version of the F-104.

"Frankly", explains President Bill Ray, "we found we lacked a broad enough line to support ourselves. Primarily we needed an automatic pilot, but the cost of such a development would have been prohibitive. Too, we needed a broader altimeter line. But these were things that couldn't be foreseen 'till we got active in the business."

As to the future GC is quite optimistic. Based on estimates that a rising consumer income and an increase in general industrial activity will spur sales of its residential and industrial controls, company marketing officials expect gross sales to total well over $60 million by 1965. (Bill Ray is even more optimistic: he forecasts sales close to $80 million by that time—twice last year's sales.)

Latest new product that GC is pushing to help bring dollars up to estimates is a transistorized capacity level control, and by late 1960 it expects to have developed a complete new line of electronic combustion controls.

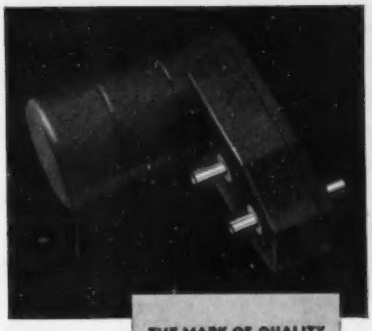
—Michael Murphy
McGraw-Hill News

News of Other Companies In the Control Field

Temco Aircraft Corp., Dallas, and **Ling-Altec Electronics, Inc.**, Anaheim, Calif., have merged to form Ling-Temco Electronics Corp. (subject to

(*Continued on page 182*)

Precision permanent magnet reversible motors...gearheads, blowers, and right-angle drives...for airborne and industrial applications



THE MARK OF QUALITY
BARBER COLMAN

VOLTAGES FROM 6 V d-c TO 115 V d-c

WITHSTAND AIRCRAFT AND MISSILE AMBIENTS

STABILIZED MAGNETS...UNDAMAGED BY INSTANTANEOUS REVERSALS

SMOOTH RUNNING...LOW COGGING AND RIPPLE

d-c small motors

Barber-Colman offers a large selection of compact, high-quality d-c motors with outputs up to 1/10 hp. Compact design . . . 1¼" to 1½" diameters. Various mountings and speeds . . . several sizes and styles of gearheads and blowers. Integral radio noise filters, magnetic brakes, and governors available for most basic designs. Right-angle drives and multiple-shaft outputs also available for special applications.

WRITE FOR NEW QUICK REFERENCE FILE on the complete line of Barber-Colman electrical components. Includes detailed specifications on a-c and d-c motors, tach generators, blowers, gearheads, relays.

BARBER-COLMAN COMPANY
Dept. F, 1848 Rock Street, Rockford, Illinois

CIRCLE 45 ON READER SERVICE CARD 45

The shrill sound of a horn
echoes in every shaft
to guard this mine's air supply against...

CUTOFF!

This is a Pennsylvania coal mine.

Deep down in the earth, hundreds of men are working at the raw sides of jagged black tunnels.

At the surface, three giant fans—each remotely situated in the surrounding countryside—send fresh air sprawling through the many miles of entryway.

The link between man and fan is 4½ miles of Rome control cable!

Engineers at this mine* selected Rome control cable for the nerves of a meticulously engineered control system that guards the mine's vital air supply. A winking light in the control room means everything is running smoothly. *But . . .*

A shrieking horn means trouble! Before gases can accumulate in the mine—jeopardizing the lives of hundreds—repair crews get the signal and start working on the failing fan.

Cable for a control system such as this must be the ultimate in reliability. "We've had experience with Rome's borehole cable and other types of Rome cable," says the chief outside electrician, "so I recommended Rome's control cable for this important job."

It went up very quickly—a crew of seven strung the first 16,000 feet over rugged, wooded and hilly terrain in only 14 days. That's *half* the time such an installation normally takes. The reason? Rome supplied a factory-assembled self-supporting-type cable to save the time and expense of on-the-job assembly.

You depend on cable, too. Just as this coal mine relies on cable to breathe, your plant relies on cable for production—to drive machines and other plant equipment. Like the mine, you can't afford to take chances on power failures.

Rome Cable manufactures various types of thermosetting and thermoplastic control cables to meet specific electrical, environmental, installation and economic requirements. Call your nearest Rome Cable salesman today for help in selecting the precise cable you need.

*Name of mine furnished on request.

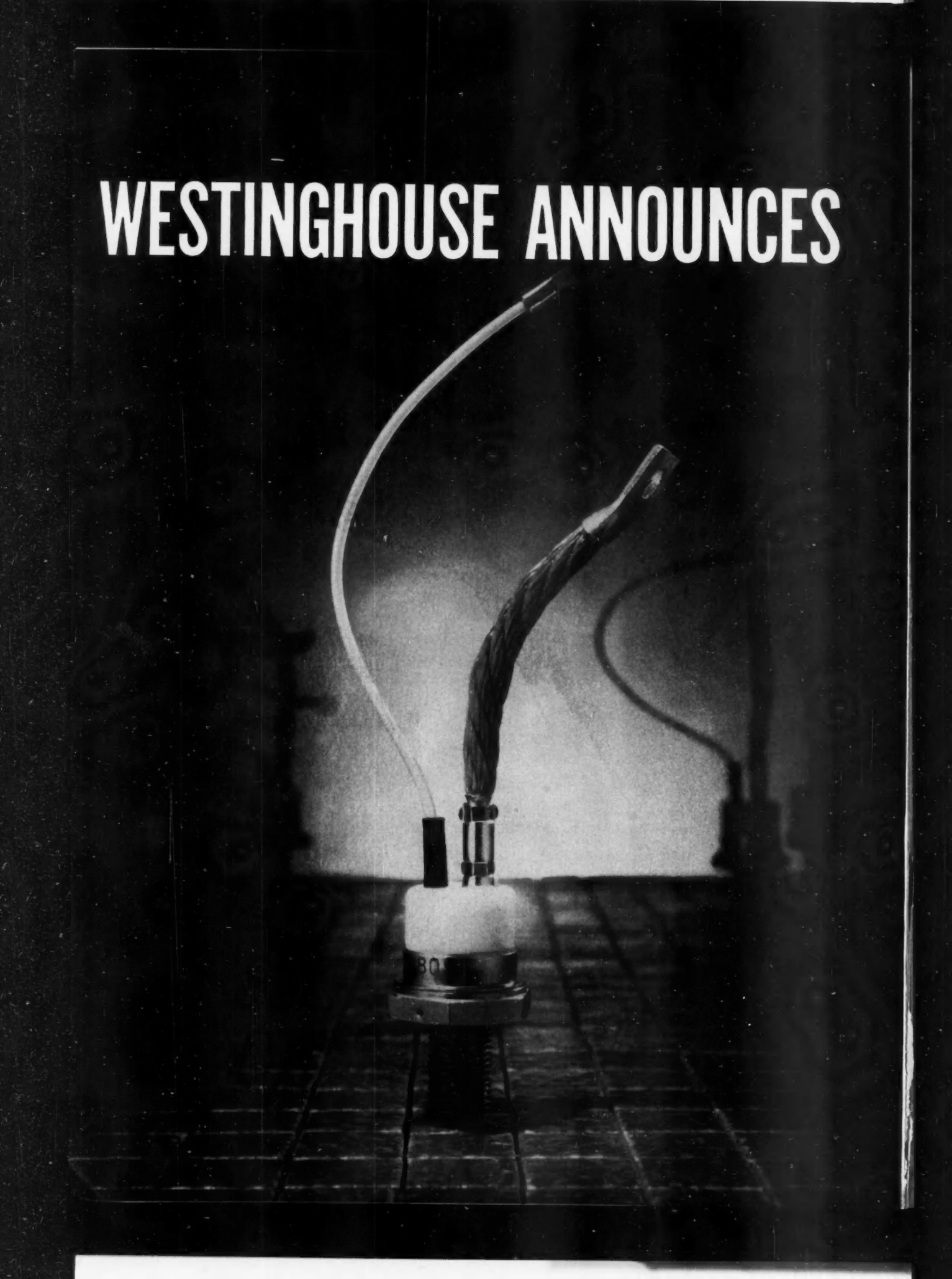
MEET THE MAN

WHO'S DEDICATED TO YOUR JOB

YOUR ROME CABLE SALESMAN

ROME CABLE
DIVISION OF **ALCOA**

WESTINGHOUSE ANNOUNCES



50 AMP "ROCK-TOP" TRINISTOR[T] CONTROLLED RECTIFIER

PROVIDES MULTI-FUNCTIONAL CONTROL OF CURRENTS AND VOLTAGES WITH FAST SWITCHING TIME AND RESPONSE RATE

New Westinghouse Trinistor "Rock-Top" construction provides high reliability, low maintenance, and positive protection against arcing at high voltages. Design engineers will find the improved electrical characteristics, listed below, can be used to advantage in a wide range of new control and switching applications.

- Lower Thermal Impedance
- Switching time 600 millimicroseconds
- Efficiencies in excess of 95%
- Simplifies circuitry
- Lower forward drop than thyratrons
- Minimum noise levels
- Parameters ideally suited for high-speed static switch functions
- Peak reverse voltage 60-360 volts

For full information or engineering assistance,
contact your local Westinghouse representative, or write:
Westinghouse Electric Corporation, Semiconductor Dept., Youngwood, Pa.

INDUSTRIAL, MILITARY, AND COMMERCIAL APPLICATIONS INCLUDE: CONVERTERS / VARIABLE FREQUENCY CONTROLS / MOTOR CONTROL / VOLTAGE REGULATION / REPLACEMENT OF MAGNETIC AMPLIFIERS / HIGH POWER MODULATION / INVERTERS / REPLACEMENT OF THYRATRONS

YOU CAN BE SURE...IF IT'S Westinghouse

SC-4111

CIRCLE 49 ON READER SERVICE CARD

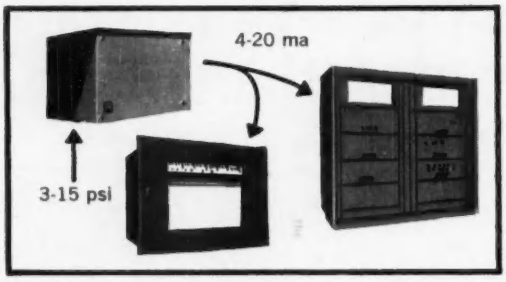
Whether you're controlling or recording

. . . now you can mix electric and pneumatic components

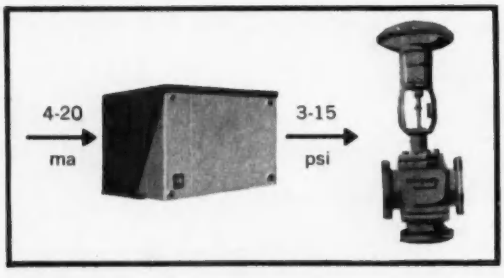
The introduction of Honeywell's complete line of *ElectriK Tel-O-Set* instruments makes electric and pneumatic components completely compatible.

Now you can add the advantages of electric instrumentation to your present *pneumatic* systems. Or, if you are designing a new system, you can use your favorite pneumatic components in an otherwise completely electric system.

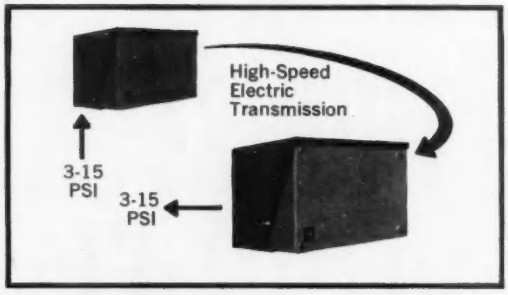
Here's an example: You have a pneumatic system but want to record a key variable on an *ElectroniK* strip chart recorder. The answer is an *ElectriK Tel-O-Set* pressure-to-current (P/I) transducer which converts the standard 3-15 psi signal to a standard 4-20 ma signal which can be fed to a data logger or computer as well as to a potentiometer.



Now let's assume that you are putting in an all-electric system but prefer pneumatic control valve operators. Here the answer is an easily installed *ElectriK Tel-O-Set* current-to-pressure (I/P) valve operator which converts the standard 4-20 ma signal to a standard 3-15 psi signal.



Used separately, *ElectriK Tel-O-Set* transducers allow you to easily intermix electric and pneumatic components. Used together, in pneumatic loops, they give you long distance high-speed transmission and eliminate the lags inherent in long runs of pneumatic tubing.



These twins have a calibrated accuracy of ± ¼% of span. They're completely transistorized for long, reliable service. Only two wires, forming a series circuit between the two transducers, are needed to carry the signal as well as the system's power. Line power is not required in the field.

Transducers are just part of the story. *ElectriK Tel-O-Set* transmitters are available to convert temperature, pressure, differential pressure, and other process variables into a current signal. To complete your system, you have a wide choice of different types of electric control . . . readouts including meters, indicators, and large case recorders . . . and final control elements.

Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne & Windrim Avenues, Phila. In Canada, Honeywell Controls Limited, Toronto 17, Ont.

Honeywell

First in Control

SINCE 1885

75th YEAR — PIONEERING THE FUTURE

Size for Size...
New ASCO Midget 3 Way
Solenoid Valve
provides

UNMATCHED FAST RETURN
UNMATCHED FAST RETURN
UNMATCHED FAST RETURN
UNMATCHED FAST RETURN

Of Cylinders and Diaphragms

INTEGRAL OVERSIZE ORIFICE SPEEDS EXHAUST CYCLE... ELIMINATES SEPARATE QUICK VENT VALVE.

New 3 way Bulletin 8317 with full ¼" diameter exhaust orifice provides quick venting of pressure from cylinders and diaphragms... assures the fastest cylinder or diaphragm return of any valve its size. It takes the place of larger, more expensive valves... eliminates need for connecting a separate quick vent valve in the circuit to speed up the exhaust cycle.

This ASCO valve has only 2 moving parts, mounts in any position. Available in normally open, normally closed and universal construction... with general purpose, explosion proof or watertight solenoid enclosures in ¼" pipe size... for pressures to 160 p.s.i.... for water to 100°F, air, gases and light hydraulic oil to 180°F.

The Bulletin 8317 Valve is available immediately from stock. **WRITE** for catalog literature and for the new ASCO Stock List & Selection Guide listing the world's largest stock of solenoid valves for immediate delivery.

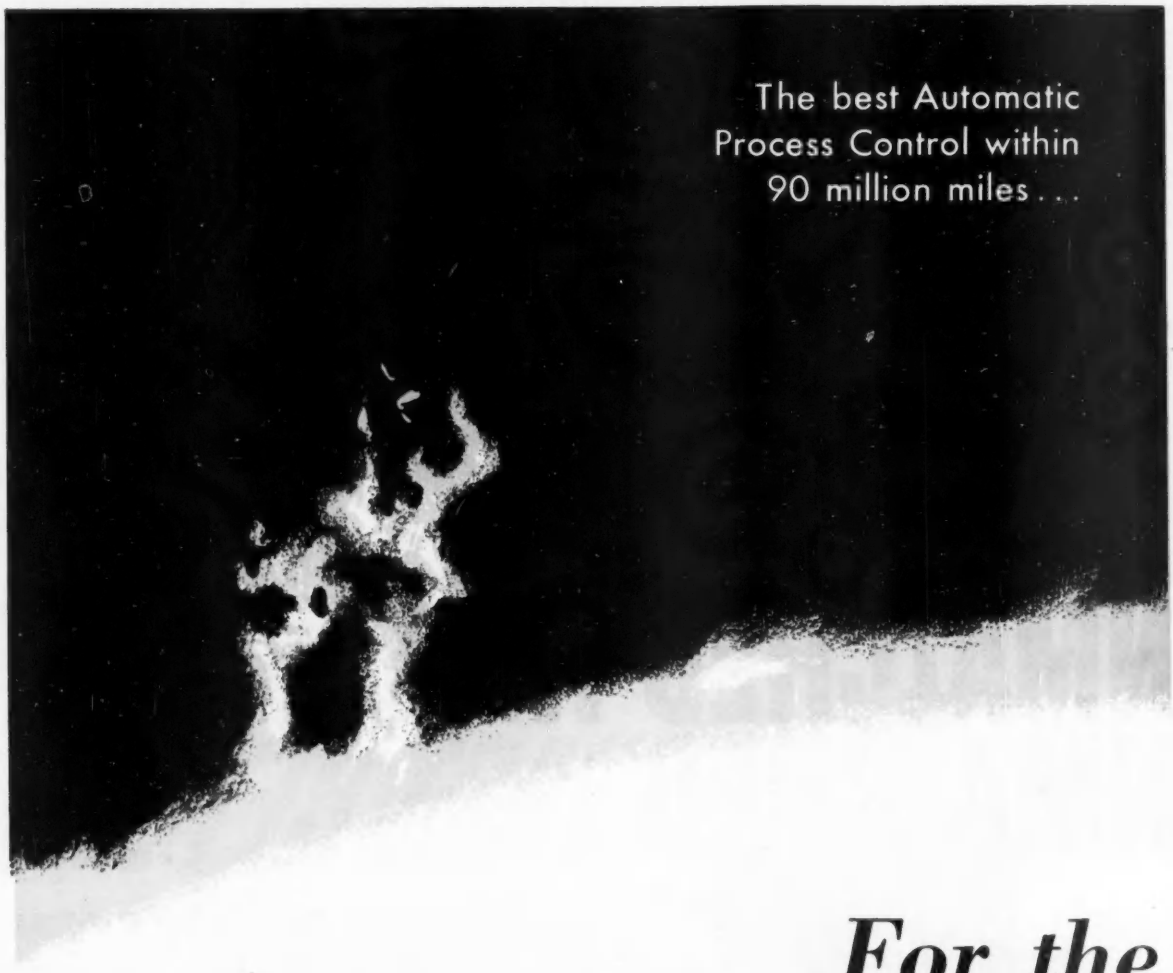
ASCO Valves

ASCO

Automatic Switch Co. 50-G HANOVER RD., FLORHAM PARK, NEW JERSEY, FRONTIER 7-4600

AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

CIRCLE 51 ON READER SERVICE CARD



For the

A battery of Wheelco Model 407 Saturable Reactor Control System Capacitrols maintain temperatures of creep-test furnaces at a leading midwestern industrial research laboratory. Control is outstanding — within ±1° F, in some instances — over a temperature span of 400° to 2200° F. Accuracy, reproducibility, and low maintenance expense were the primary reasons for selecting Wheelco.

The Mark of Quality

BARBER COLMAN

Industrial Instruments • Automatic Controls • Air Distribution Products • Aircraft Controls • Electrical Components •

finest under the sun... Wheelco Process Control

Controlling solar fusion is a little beyond us — right now. But for down-to-earth process control problems, Wheelco will furnish practical answers. A Wheelco system can be "custom-fitted" to your needs — so wide, versatile, and varied are the Wheelco standard lines of indicating-recording-controlling instruments, combustion safeguards, and gas chromatography systems. Include Wheelco in your process control plans — factory-trained and field-experienced engineers at your nearby Wheelco Branch Office will be glad to help you.

WHEELCO INSTRUMENTS DIVISION

Dept. F, 1548 Rock Street
Rockford, Illinois, U.S.A.

Barber-Colman of Canada, Ltd.
Dept. F, Toronto and Montreal, Canada
Export Agent: Ad. Auriema, Inc., N.Y.

BARBER-COLMAN COMPANY

Small Motors • Overdoors and Operators • Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

CIRCLE 53 ON READER SERVICE CARD 53

TO THE ENGINEER

who can't tolerate a lapse of memory

If you're working on a think machine that can't afford to break its train of thought, consider AE's pint-size, fast-stepping OCS switcher. Unlike electron tubes and relays, this sophisticated device won't lose stored memory in the event of power failure or circuit interruption.

Besides, it can do the work normally assigned to whole banks of relays.

The AE Series OCS will follow or initiate a prescribed series of events or cycles at 30 steps per second impulse-controlled, or 65 steps per second self-interrupted. Any programming sequence can be set up on one to six cams with as many as 36 on-and-off steps per cam. And each cam will actuate as many as six contact springs.

In any event, if your designs involve relays or stepping switches, AE circuit engineers may be able to save you a pretty penny. Or, if you'd like to leave the switching to us, we're equipped to supply prewired and assembled, custom-built control units, *or* help you develop complete control systems.

To explore the matter, just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1698-H: *Rotary Stepping Switches;* Circular 1702-E: *Relays for Industry;* and our new 32-page booklet on *Basic Circuits.*

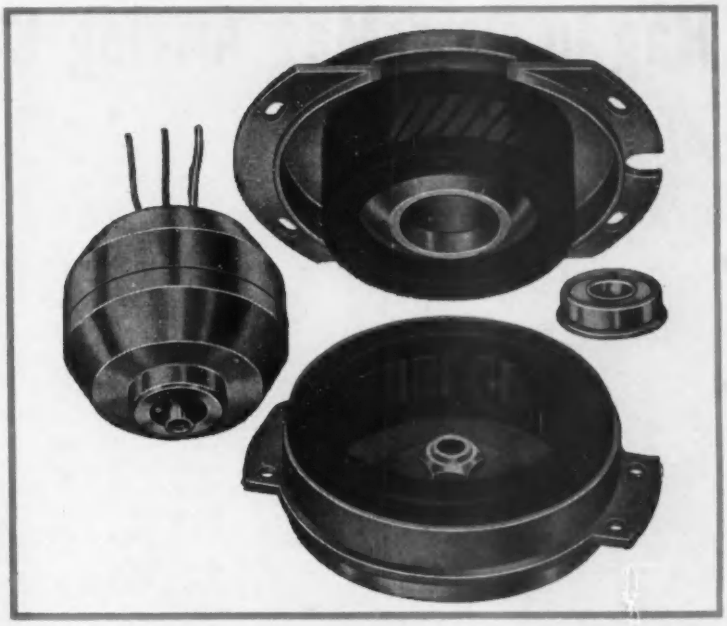
AUTOMATIC ELECTRIC GENERAL SYSTEM

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

NOW–Ketay "packaged" Gyro components

- safeguard system accuracy
- save testing and machining



Norden's Ketay Department, an acknowledged leader in the rotating component field, is now able to deliver gyro component "packages" tailored to your specifications . . . ready for installation. This precision pre-assembly saves you expense and problems because:

TESTING, simulating *your* application, is handled by Ketay.

MACHINING of mounts and fittings is accomplished at Ketay . . . saving you machine time and engineering time.

RELIABILITY is further ensured, for the gyro "package" is an entity wholly tailored to a pre-determined function . . . not an assembly of individually modified components. In addition, sets of such packages can be perfectly matched.

Components shown above—Synchro, Torquer and Spin Motor—are typical. Their specifications are tabled below. Other Ketay gyro component "packages" are Induction Pickoffs, Pancake Resolvers, D.C. Spin Motors and a unique D.C. Voice Coil Torquer giving a linear force of .55 grams per milliampere of current.

TYPICAL SPECIFICATIONS

SYNCHRO TRANSMITTER TYPE SP-152

Input Voltage (to Rotor)—400 cps—volts	26
Input Power—watts	1.0
Input Impedance (stator shorted)	110+j 36
Input Impedance (stator open)	89+j 230
Transformation Ratio	.454
Output Impedance (Rotor open)—ohms	27+j 44
Output Voltage—volts (line to line)	11.8
Voltage Gradient—volt/degree	0.206
Total Null Voltage (mv. max.)	30
Electrical Accuracy (Max. Error from E.Z.)—minutes	±3.0

(Tighter accuracy tolerances available for applications requiring limited ranges of rotation.)

A. C. TORQUER MOTOR TYPE SP-170

	Fixed Phase	Control Phase
Rated Excitation Voltage—volts	26	40
Frequency (cps)	400	400
Current—(mv.)	230	226
Power—watts	3.1	4.6
Power Factor	.517	.505
Resistance—ohms	58.5	89.3
Reactance—ohms	85.5	152.5
Impedance—ohms	113	177
Effective Resistance—ohms	218	348
Capacitor for Unity Power Factor—mfd	1.35	2
Torque at stall (min.)—oz.in.	1.0	

Operating Temperature Range—minus 55°C to plus 125°C

A. C. SPIN MOTOR TYPE SP-167

Input Voltage (line to line)—volts	26
Frequency—(cps)	400
Input Line Current (mv.) at stall condition	350
Total Input Power (watts) at stall condition (max.)	10
Input Line Current (mv.) at 24,000 rpm.	300
Total Power (watts) at 24,000 rpm. (nominal)	5.5
Stall Torque—(min.) in.oz.	.34
No-load Speed (rpm.)—(in air)	24,000
Run-up time with rated voltage (in air) to NLS—sec. max.	90
Moment of Inertia $Gm.Cm^2$	190
Angular Momentum $Gm.Cm^2/Sec.$ at 24,000 rpm.	475,000
Dynamically balanced to within $10x10^{-6}$ oz.in. max. unbalance	
Coasting time (in air) (min.)	2½
Total weight—gms.	151

Ambient Temperature Range—Minus 55°C. to Plus 125°C.

KETAY DEPARTMENT

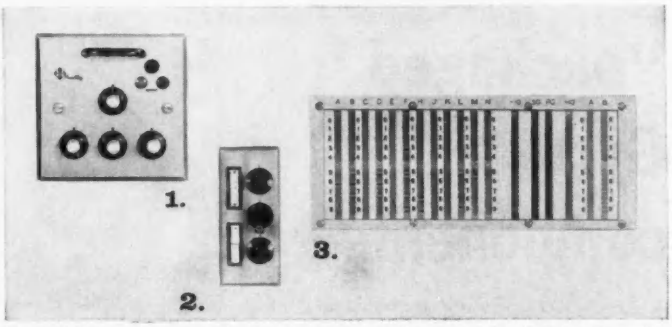
NORDEN
DIVISION OF UNITED AIRCRAFT CORPORATION
Commack, Long Island, New York

CIRCLE 55 ON READER SERVICE CARD 55

Hagan PowrMag Analog Computer Control

simple as

1 2 3



PowrMag systems embody the highest degree of flexibility. Simple, efficient electrical design utilizing long-lived and trouble-free solid state components, and rugged mechanical construction suit the system for a variety of industrial process control applications.

1. *Magnetic Control Unit*

This magnetic amplifier, operating on 1-9v DC, may be used individually, as a single 2 or 3 mode controller, or as one element in a large system. Each control unit may be removed from the front of the panel for easy interchangeability. The basic unit is easily converted to other modes by the addition of interchangeable, plug-in circuits for *all* common control operations. Inventory is reduced to the one basic unit. Unaffected by shock or vibration, PowrMag has no moisture, dirt, leakage or freezeup problems—3.5 watts of unregulated 110v, 60 cycle AC. Size—5¼" x 5¼".

2. *Remote Control Station*

These stations provide for remotely established set points and required manual control operations. Full station may contain two single or ganged potentiometers, one switch and two meters. Size—2¼" x 5¼". Half stations available with set point, bias or ratio dial and output signal indicator. Size—2¼" x 3⅛". Each station uses 12-wire, color-coded electric cable with MS-type connector. Front mounting and removal make it ideal for the compact console installations required for centralized control.

3. *Patchboard*

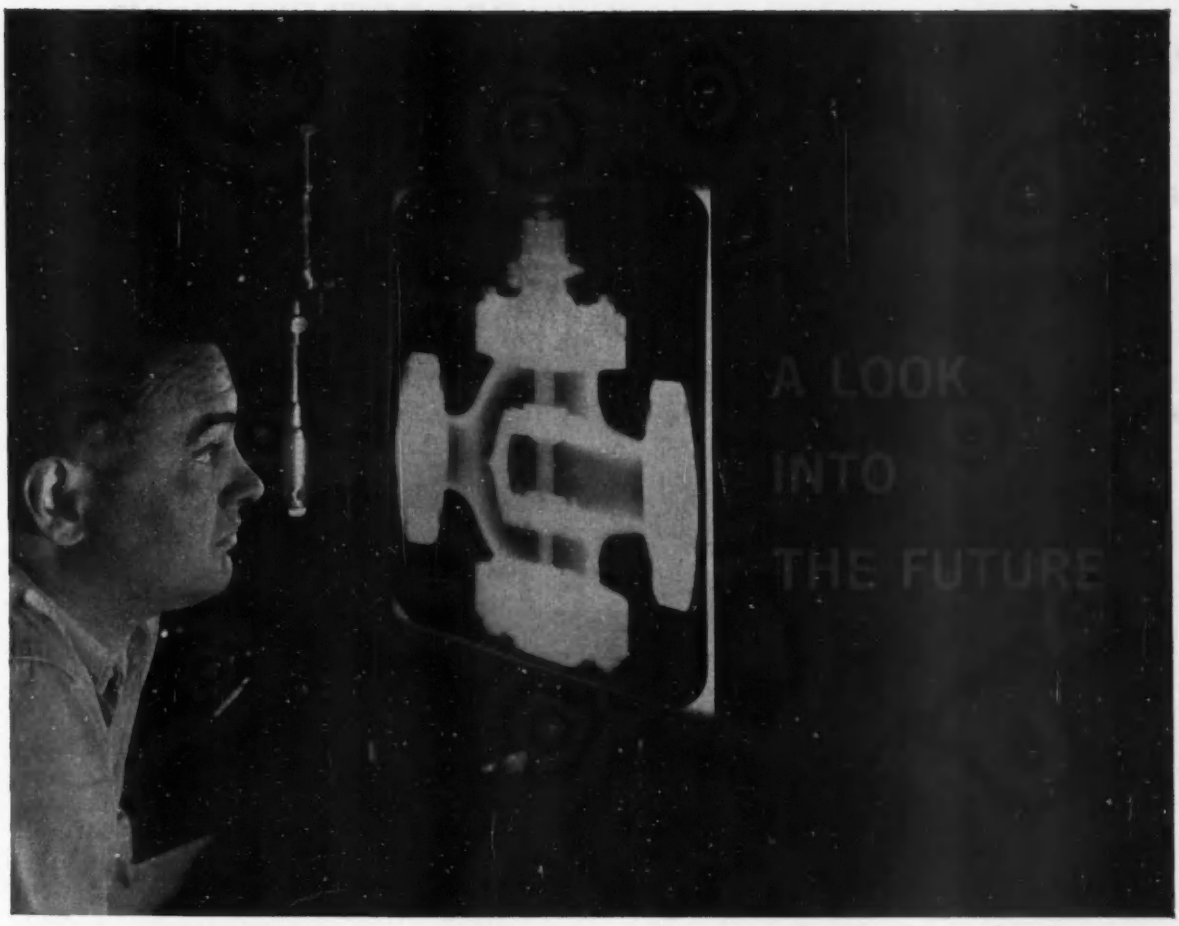
Interconnecting the system in any desired manner, via color-coded electrical cable, the patchboard requires no solder connections or terminal boards—all connections are made by special taper pins. Each connection is identified by an alphanumeric combination. Numbers, run vertically, identify the components in the system, such as magnetic amplifiers, controllers, transducers, etc. Letters, run horizontally, identify the connectors leading into the patchboard. DC control power bus is in the center section—no AC voltages are used in the patchboard.

Easy front access permits simple changing of operations. Additional loops or components are readily added to the system.

A letter or phone call will bring you complete information on the PowrMag system. **Ask for Bulletin MSP-163.**

HAGAN
CHEMICALS & CONTROLS, INC.
HAGAN CENTER, PITTSBURGH 30, PENNSYLVANIA

HAGAN DIVISIONS: CALGON CO. — HALL LABORATORIES — BRUNER CORP.

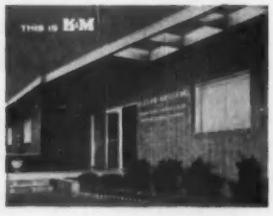


Neither stargazer nor mystic, this K & M technician can nevertheless see into the future. His crystal ball is a small mass of radioactive Iridium; his fortune-telling cards, gamma-ray pictures of critical valve assemblies. With these pictures he searches out the kind of subtle flaws and tiny imperfections that could become trouble spots at some future time. And so he is able to predict and prevent in-service failures and malfunctions.

Radiographic inspection is just one way in which K & M works to insure a long and healthy service life for its products. K & M's in-plant quality control facilities range from a contour comparator, for precision checking of small parts, to a 4000-gpm flow test loop, where sample valves from the production line are tested for on-stream performance. Micrometer and calipers play an important part, too, for each K & M valve is subjected to more than eight hundred dimension check-outs before it reaches the shipping crate. It's either perfect, or "no go."

K & M's meticulous standards of quality control are neither myth nor magic . . . just good business — for us, and for you.

For a more detailed view of our plant and production practices, send for the well-illustrated, informative brochure, "This Is K & M."



K&M

diaphragm control valves

KIELEY & MUELLER, INCORPORATED

Our 79th Year

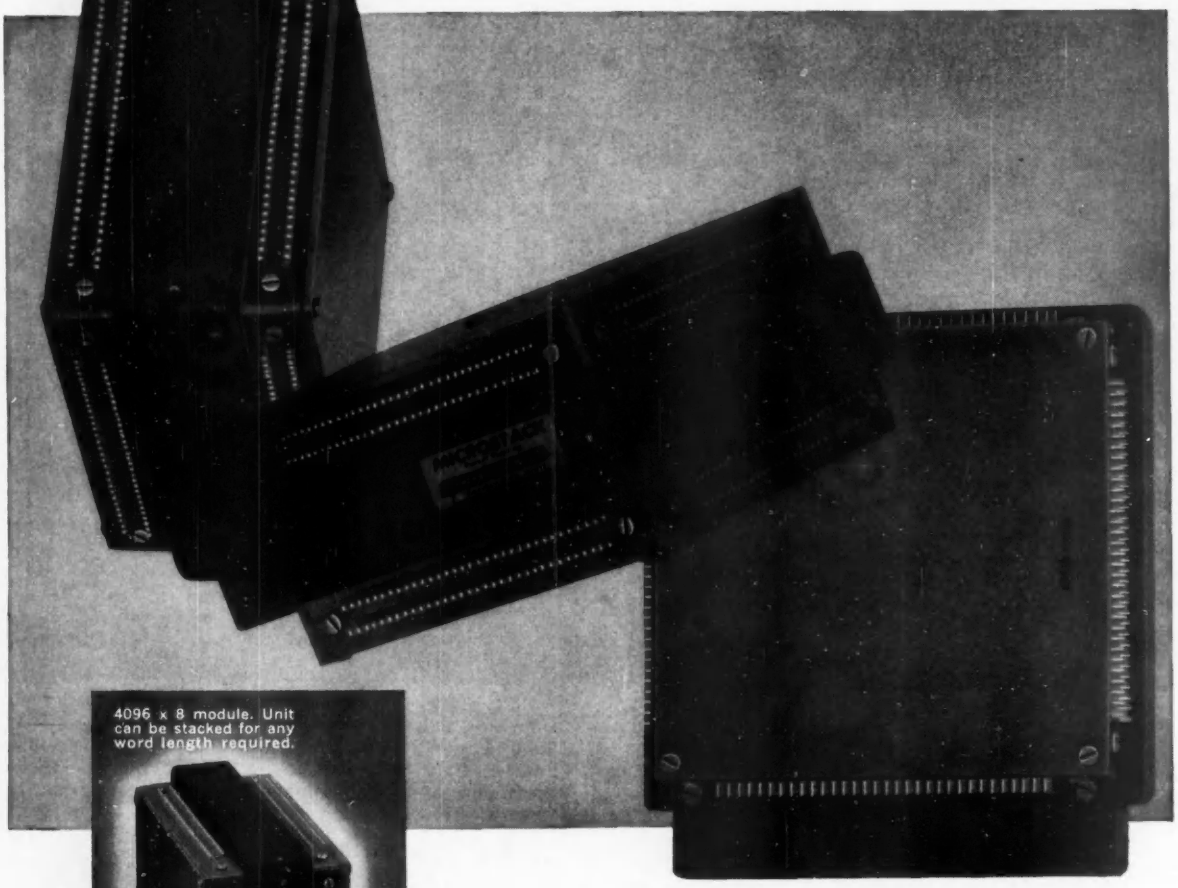
Oldest Pressure and Level Control Valve Manufacturer
64 Genung Street, Middletown, New York

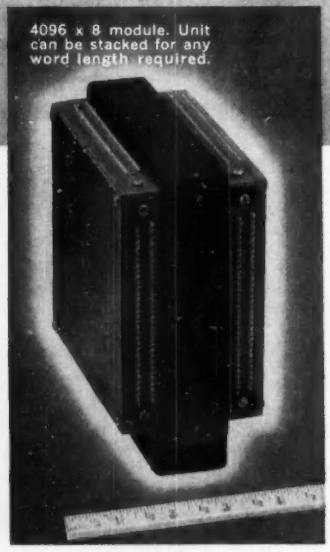
E.A. 1902

New temperature controlled MICROSTACK® meets

-55°C to +85°C

MILITARY REQUIREMENT





The General Ceramics MICROSTACK, one of the most important advances in memory core packaging, now operates in a temperature range of from —55°C to +85°C. Core characteristics remain constant. By maintaining temperature stability inside the MICROSTACK unit, General Ceramics engineers have developed a memory core package that is smaller, more rugged, requires no external cooling or heating, and meets MIL shock and vibration specifications.

For additional information, please write on company letterhead. Address inquiries to Section CE.

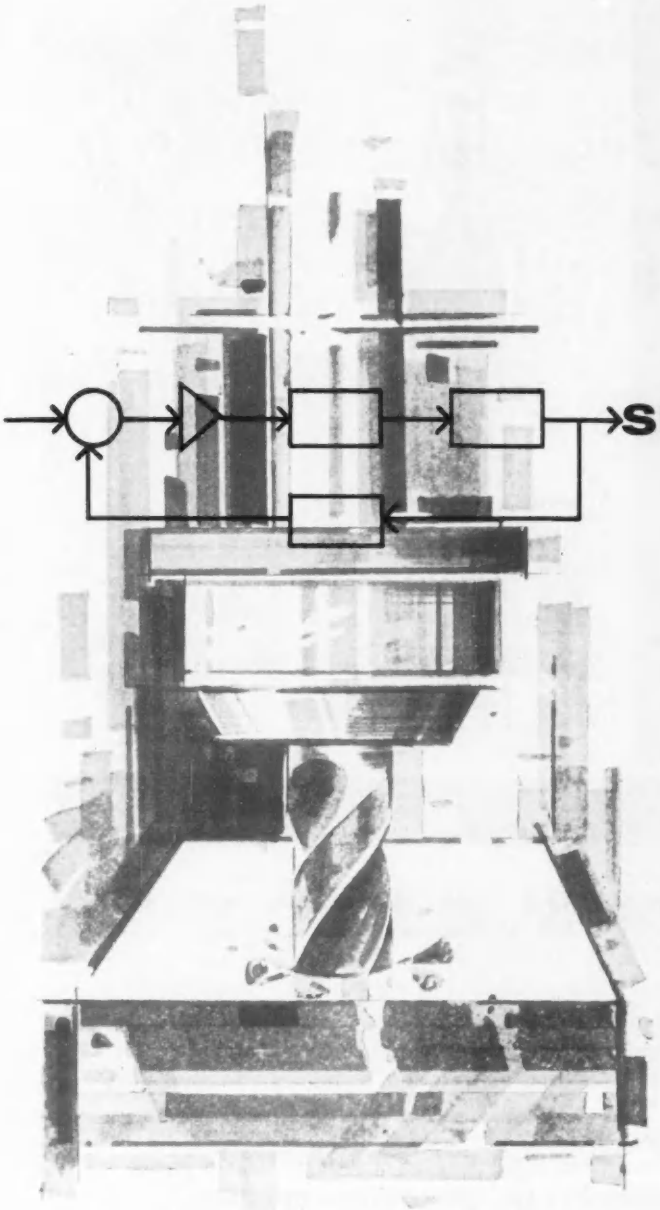
DIVISION OF INDIANA GENERAL CORPORATION

APPLIED LOGIC DEPARTMENT

GENERAL CERAMICS

KEASBEY, NEW JERSEY, U.S.A.

TECHNICAL CERAMICS, FERRITE AND MEMORY PRODUCTS



electrohydraulically speaking...

how accurate, how reliable is a SERVOSYSTEM?

The servovalve is the prime determining factor of reliability and accuracy in a Servoactuation system. In a drive control system which includes servovalves, amplifiers, actuators and necessary power supplies, exceptional valve performance is required. Use of Moog's servovalve and unitized approach to system design insures maximum component performance.

SERIES 71 SERVOVALVE

SERIES 72 SERVOVALVE

comparatively speaking . . .

WHAT ADVANTAGES DO ELECTROHYDRAULIC SERVOSYSTEMS OFFER?

". . . First and foremost, they provide dynamic response capabilities completely out of the range of any other types of control . . . Their range of dynamic response is much higher than the fastest pneumatic system . . .
The next important advantage offered is size and weight . . . the complete hydraulic system for all but the very low horsepower applications is lighter than any other type of powered control system . . .
Third, the systems are rugged. They can operate under severe environmental conditons."*

*Bernard A. Johnson NCIH Article 13th Annual Meeting
"The Application of Electro-hydraulic Servo Valves to Industrial Control"

MOOG:

SERVOSYSTEMS IN INDUSTRY

WRITE FOR PB110

MOOG SERVOCONTROLS, INC. INDUSTRIAL DIVISION EAST AURORA, N. Y.

RW-300

the most field-reliable computer control system . . .

FOR AUTOMATIC CONTROL IN STEEL MILLS

Applied to the operation of a blast furnace, RW-300 digital computer control can result in a 2 to 4 percent increase in production rate or decrease in coke consumption. Measured over a year, such improvements in the return from *one* furnace can equal the investment in an RW-300 system. Similar cost reductions and production increases can be realized through computer control of sintering plants, open-hearth furnaces, oxygen converters, rolling mills, annealing and plating lines, and other processes in existing or new steel mills.

In an effort to boost profits by reducing costs and increasing throughput, many leading steelmakers are now considering computer control, and uppermost in their minds is the question of system reliability proven in the field. More than a dozen RW-300 systems are now operating around the clock in rugged industrial environments.

For further information, call or write Mr. Raymond E. Jacobson, Director of Marketing, Dept. CE-1076-1.

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

a division of ***Thompson Ramo Wooldridge Inc.***

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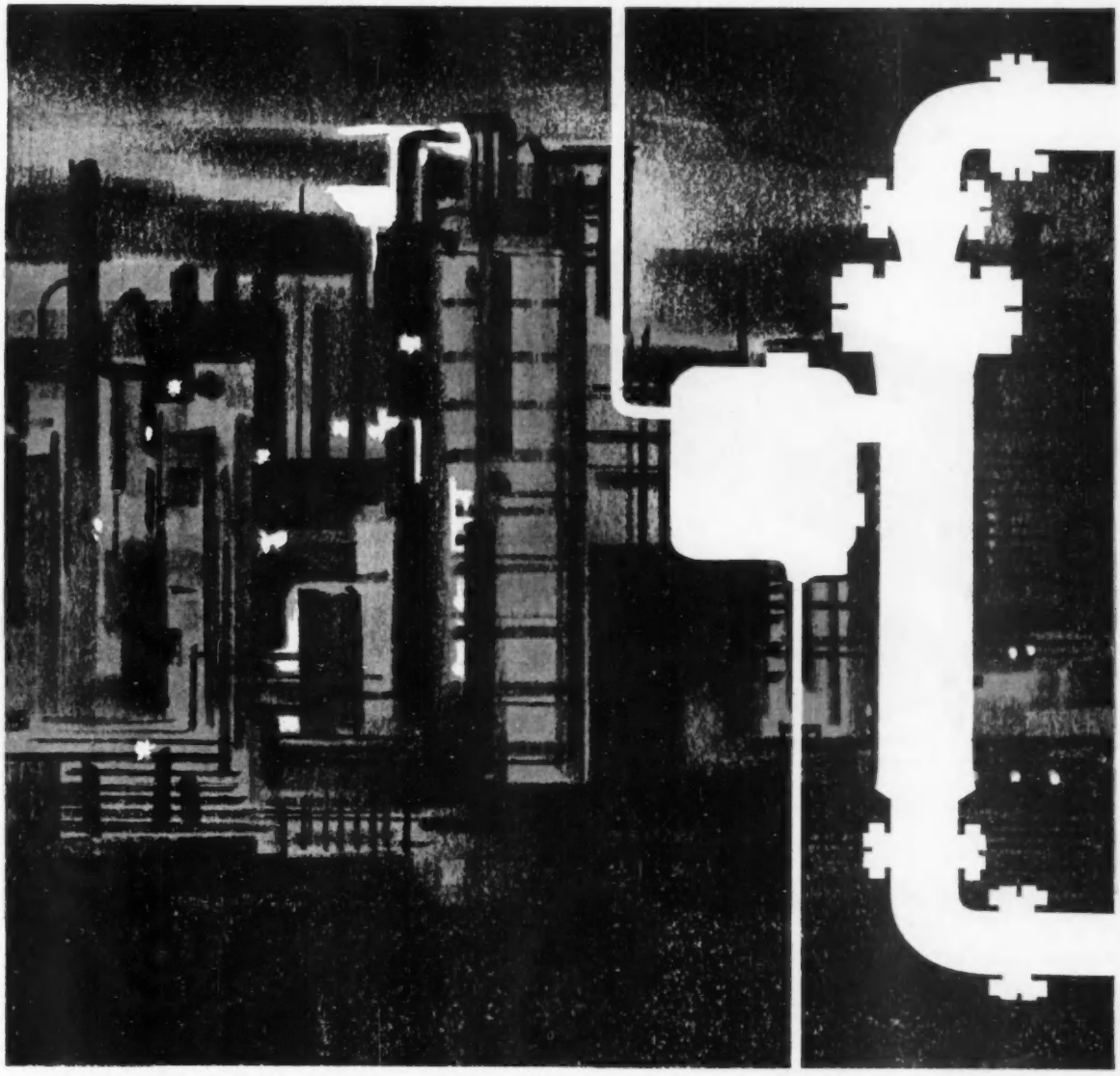


Fisher Level-Trols—universally accepted in the power and process industries

High in sensitivity and accuracy! For full float range operation the Fisher Level-Trol is factory calibrated or zero adjusted to produce an accurate 3 to 15 psi or 6 to 30 psi signal output. Designed, engineered and universally accepted for most liquid level control, liquid level indication and interface control problems. Has simple liquid level adjustment indicating dial—combined pneumatic proportional band and specific gravity adjustment. Heavy-duty built—easy to operate—simple to service. Available with cage units for external mounting or internal top or side flange mounting with float sizes from 14" to 120".

Write for Bulletin F4A for full details.

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD... CHANCES ARE IT'S CONTROLLED BY...

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

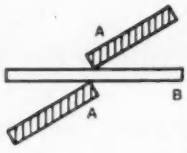
FISHER® Controls

SINCE 1880

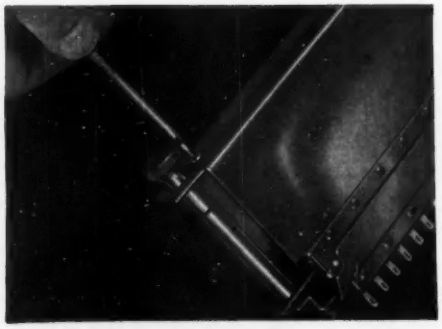
new north multi-contact multi-purpose connectors

These new, compact and highly efficient plug and receptacle type connectors provide maximum connection concentration in a limited space. They are designed for electronic applications in cable-to-cable, cable-to-fixture, fixture-to-fixture, and are available in 40, 60, 80 and 100 pin sizes.

A prongs of fork contact
B flat pin contact



Firm contact is assured by the unique torsion pressure principle in which beveled end flat blade male connectors seat into flat, fork shaped female blades placed at an angle to the male plugs—assuring double contact, providing minimum contact resistance.



The new design of the mounting hardware features a handy locking bolt for securing the plug to the receptacle and a removable cover with captive screw for rapid wiring or inspection. The permanent cable clamp is adjustable to accommodate varied cable sizes. All connectors are available with either solder or taper tab terminals.

For full details, write

ELECTRONETICS DIVISION

NORTH ELECTRIC COMPANY

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60-C-2

A NEW, ULTRA-SONIC, NON-CONTACT SENSING AND SWITCHING SYSTEM

SONAC

Here truly is a new dimension in automated controls! Delavan's new SONAC uses ultrasonic energy for its "beam". This new concept offers many advantages over available sensing devices. SONAC has no lamps to burn out... nothing to replace... eliminates down time. SONAC is unaffected by vibration, dust, industrial contamination or ambient light. SONAC will sense ferrous and non-ferrous metals, liquids or solids, transparent or opaque materials, yet requires less power than an ordinary flashlight. These are a few of SONAC's advantages.

Send for this complete descriptive booklet. There's no cost or obligation.

PATENTS PENDING

DELAVAN
Manufacturing Company
WEST DES MOINES • IOWA

NEW! 16 Low cost all-electronic totally-transistorized DIGITAL MULTIMETERS

Now in a single 5¼" or 8¾" x 19" panel Digital Multimeters for measuring any combination of AC/DC volts, AC/DC ratios, and resistance, with new pre-amps for higher sensitivities, optional electrical output and print command capabilities!

FLIP-TOP BOX CONSTRUCTION FOR EASY MAINTENANCE.

- 50 readings per second, average
- Inline "SUPER-NIXIE" readouts
- 0.01% accuracy
- 1000 megohm input impedance
- Automatic, manual and remote ranging
- Automatic polarity
- Twin Zener diode internal reference
- Front panel sensitivity control
- Etched circuits, plug-in card construction
- Will operate directly in multi-point scanning and print-out data logging systems without any additional circuitry or auxiliary equipment.

MODEL 840
DC Volts/DC Ratios

MODEL 841
DC Volts/DC Ratios/Resistance

MODEL 842
DC Volts/DC Ratios/AC Volts

MODEL 843
DC Volts/DC Ratio/AC Volts/Resistance

MODEL 844
DC Volts/Ratio/DC Pre-Amplifier

MODEL 845
DC Volts/Ratio/Resistance/DC Pre-Amplifier

MODEL 846
DC Volts/Ratio/AC Volts/DC Pre-Amplifier

MODEL 847
DC Volts/Ratio/AC Volts/Resistance/Pre-Amplifier

MODEL 848
DC Volts/Ratio With Electrical Outputs

MODEL 849
DC Volts/DC Ratios/Resistance With Electrical Outputs

MODEL 850
DC Volts/DC Ratios/AC Volts With Electrical Outputs

MODEL 851
DC Volts/DC Ratio/AC Volts/Resistance With Electrical Outputs

MODEL 852
DC Volts/Ratio/DC Pre-Amplifier With Electrical Outputs

MODEL 853
DC Volts/Ratio/Resistance/DC Pre-Amplifier With Electrical Output

MODEL 854
DC Volts/Ratio/AC Volts/DC Pre-Amplifier With Electrical Outputs

MODEL 855
DC Volts/Ratio/AC Volts/Resistance Pre-Amplifier With Electrical Outputs

Many variations of these basic models including AC ratiometers, milliohmmeters, microvoltmeters and specialized measuring instruments tailored to individual systems requirements are available in the same physical configurations. ***Ask your EI sales office or representative for complete specifications today!***

Electro Instruments, Inc.

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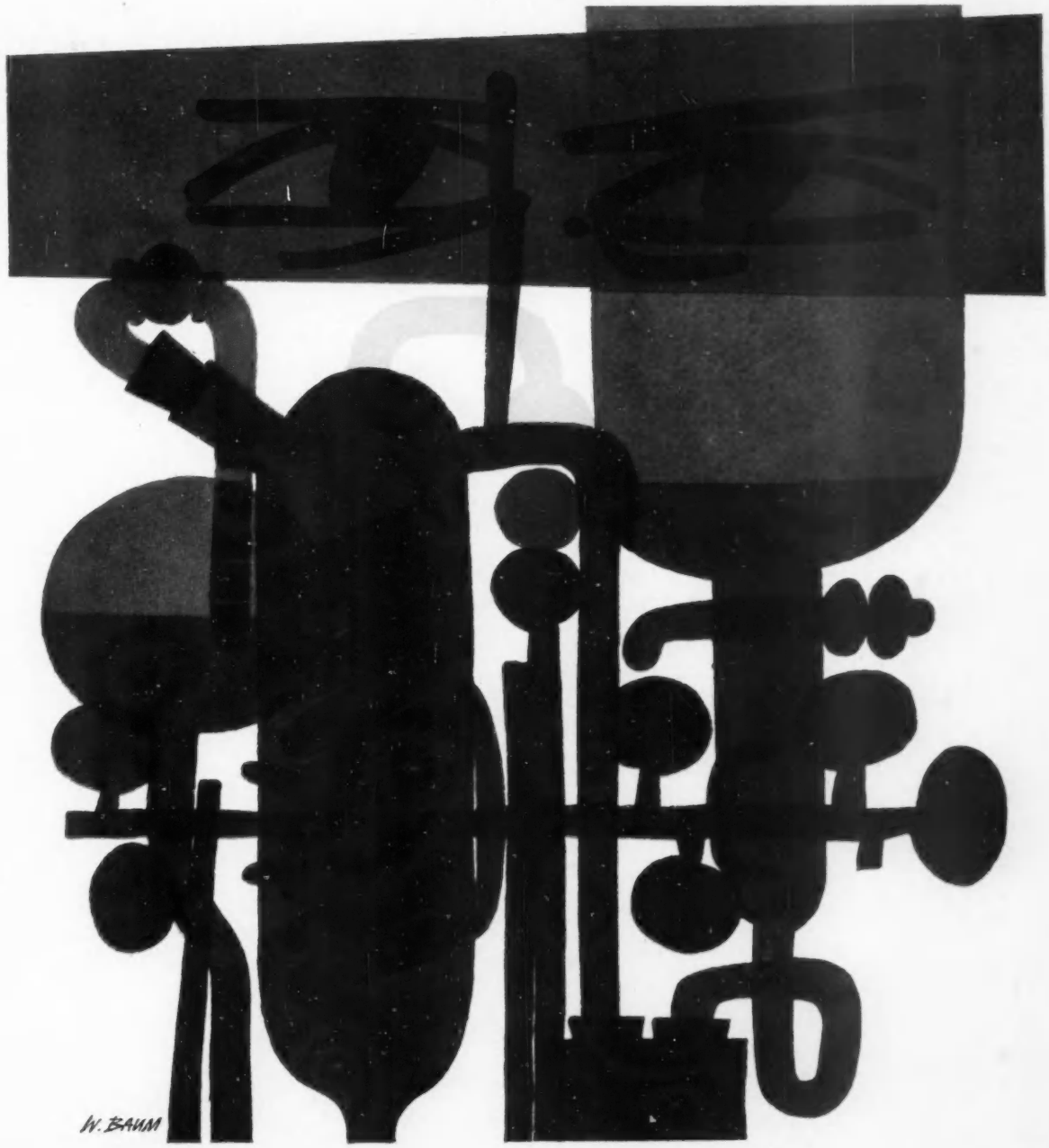
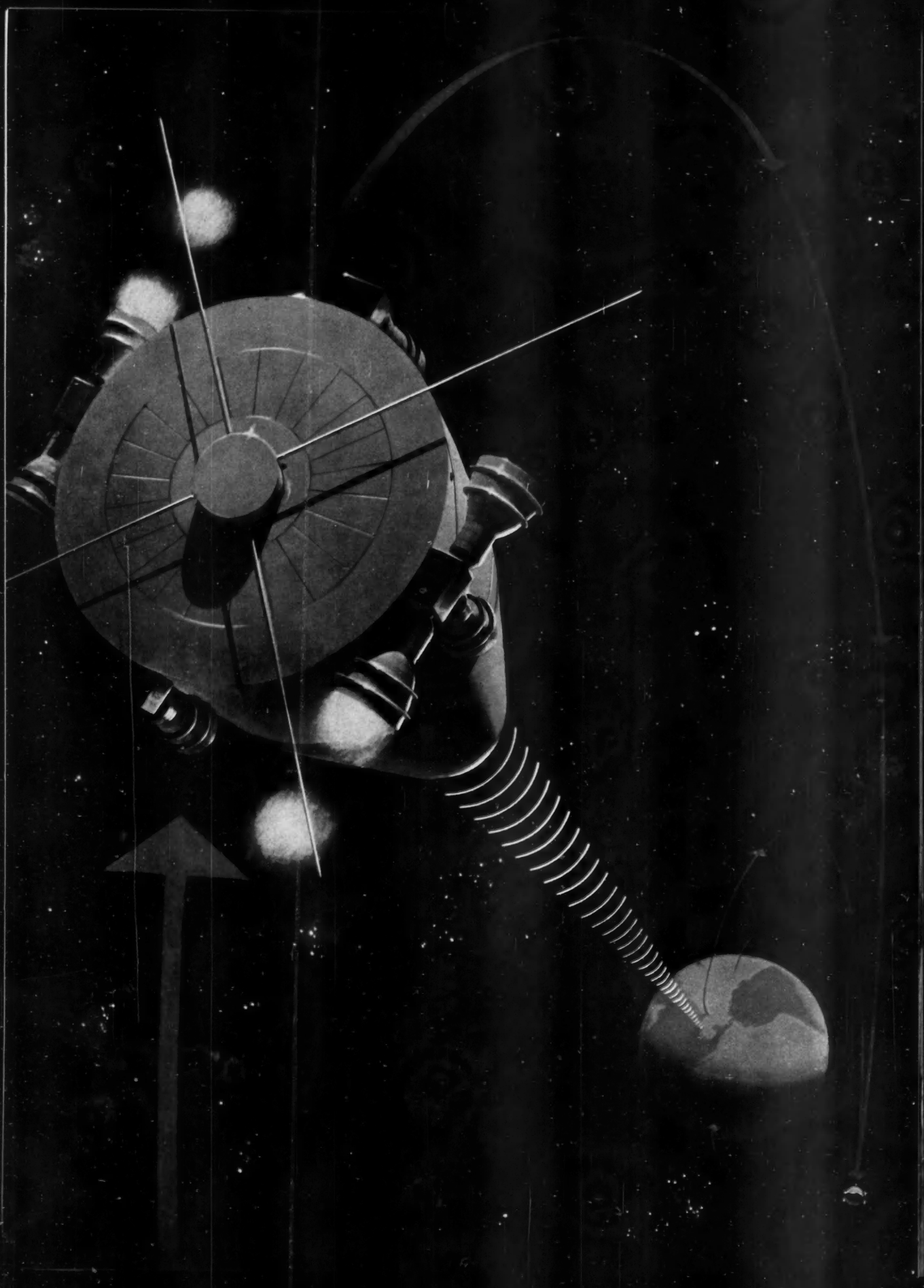
FORECAST

Laboratories for space science at Martin are now studying and forecasting the physical, psychological, and biological factors that will affect man in space . . . another tremendously fascinating program which attracts persons with exceptional professional abilities. If you have these abilities, you are invited to communicate with N. M. Pagan, Director of Technical and Scientific Staffing (Dept. 1-D) The Martin Company, P. O. Box 179, Denver 1, Colorado.

MARTIN
DENVER DIVISION





MARQUARDT PAT-C* SYSTEM MAKES POSSIBLE PRECISION SPACE CONTROL

New control gives 3500 to 1 modulation and .001 pound-seconds impulse

Orbit correction, station keeping and attitude control of a 24-hour surveillance satellite which must orbit in a fixed position 24,000 miles above a predetermined point on earth, is but one unique application of PAT-C—position, attitude, trajectory control system—a development of The Marquardt Corporation's Controls and Accessories Division.

The PAT System is a highly responsive jet reaction control which controls the flight path, the position and attitude of a space vehicle as a result of intelligence inputs from the vehicle guidance system or ground control. The system is capable of providing the necessary corrective action based on simple positions and velocity air signals or will respond to the demand of complex guidance computers in the system. The thrust level can be adjusted over a range of 3500 to one (or more in some cases) with the same set of rocket nozzles; proportional control of thrust from 0 to full thrust is possible. Impulse imparted to the vehicle can be controlled accurately over a wide range down to a few milliseconds in duration—with a one lb. thrust nozzle as low as 0.001 pound-seconds. In the attitude control mode, the PAT system can maintain pointing accuracies not possible with other systems due to its low propellant consumption in limit cycle operation.

In a typical case, an accuracy of 0.1 seconds of arc can be held for 1000 hours with 40 lbs. of propellant.

Marquardt's fifteen years of research, development and production has resulted in state-of-art advancements in a wide range of electronic, electro-mechanical, pneumatic and hydraulic controls and accessories. For example, a pneumatic servo actuator is now available for 1600°F service—and severe nuclear radiation environments.

For additional information concerning the PAT-C System or other C & A capabilities, contact Dick Oblinger, Chief Applications Engineer-Controls and Accessories, The Marquardt Corporation.

Engineers and Scientists experienced in these or related fields will find it rewarding to discuss their career futures with Marquardt. Founded in 1944, Marquardt now has a staff of 5,000—two out of three are professional people. The company's growth is a parallel to the atmosphere of challenge and rewarding accomplishment that has existed since the firm's beginning.

Shown in photograph below—Marquardt engineers discuss a full scale mock-up of a complete self-contained PAT-C unit designed for application to space vehicles.

CONTROLS & ACCESSORIES DIVISION

THE Marquardt CORPORATION

16555 SATICOY STREET, VAN NUYS, CALIFORNIA

ASTRO ◆ COOPER DEVELOPMENT DIVISION
◆ OGDEN DIVISION ◆ POMONA DIVISION
◆ POWER SYSTEMS GROUP

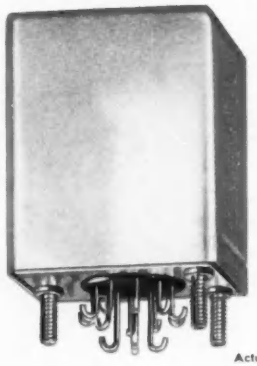
CORPORATE OFFICES: VAN NUYS, CALIFORNIA

*POSITION—ATTITUDE—TRAJECTORY CONTROL SYSTEM

CIRCLE 67 ON READER SERVICE CARD

"Shock Troop" Performance

...withstands 10g 500 cycle vibration



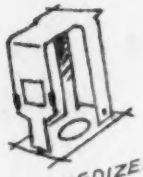
Actual Size

E ESSEX ENGINEERED E

RBM MINIATURE HERMETICALLY SEALED RELAYS

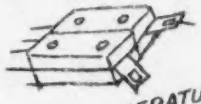
The reliability of this relay under severe conditions of vibration and shock has been field-proven in many applications. It is another example of how R-B-M's production maturity and complete facilities can eliminate many of your engineering problems.

BHSM AND BHSM-HT TYPES HAVE THESE FEATURES



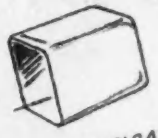
"RUGGEDIZED" WELDED RELAY AND BRACKET ASSEMBLY

DEPENDABLE X-BAR CONTACTS



HIGH TEMPERATURE PILE UP INSULATORS (HT VERSION)

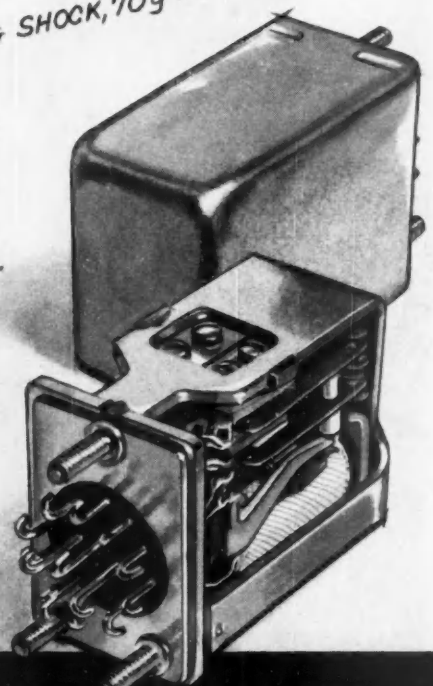
KEL-F COIL BOBBIN AND CLASS H MAGNET WIRE (HT VERSION)



HERMETICALLY SEALED OR DUST COVER AVAILABLE

OPERATING BENEFITS

- 125°C OPERATING AMBIENT
- TEMP. RANGE } 22700 BHSM TYPE, -55°TO+85°C 22800 BHSM HT TYPE, -65°TO+125°C
- COIL UP TO 130 V.D.C. } SENSITIVITY 0.2 W. MIN. PER POLE MAX. COIL DISSIPATION 3.75 W.
- CONTACTS-MAX. 4 PDT 3 AMP. AT 32 V.D.C. OR 115 V.A.C. (NON-INDUCTIVE)
- SPECIAL CONTACTS AVAILABLE FOR LOW LEVEL OR DRY CIRCUIT APPLICATIONS
- APPROX. WEIGHT - 3.25 OZ.
- 30g OPERATING SHOCK, 70g NON-DESTRUCTIVE



Consult your local RBM Product Application Engineer or write for Bulletin BHSM-1.

RBM Controls Division

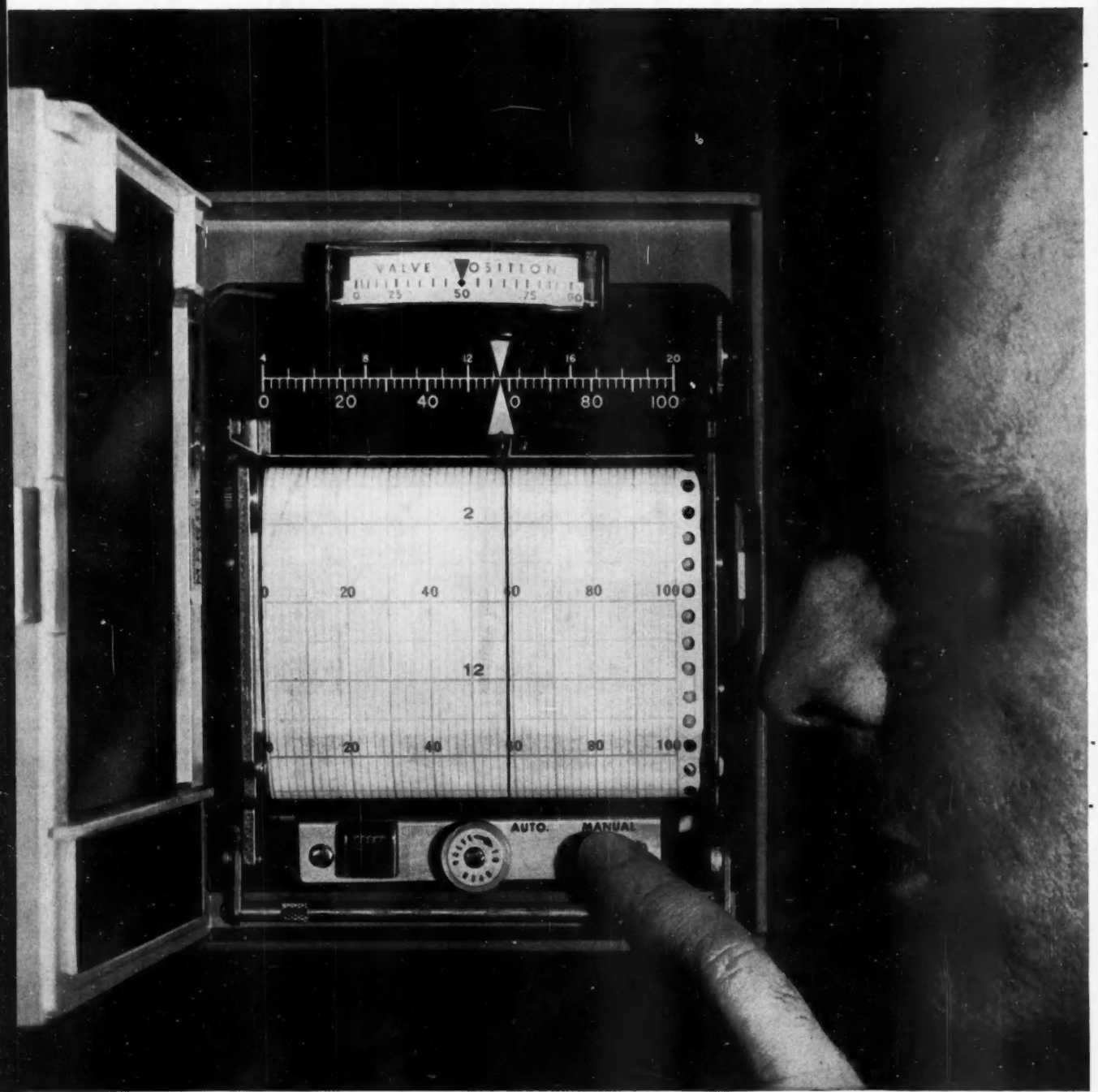
ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

Factories Located at Peru, North Manchester and Logansport, Indiana

AC Seeks and Solves the Significant—AC has earned an enviable reputation for scientific accomplishment with national defense projects such as AChiever inertial guidance systems. But AC is not limiting its goal to leadership in the international technological race. Utilizing scientific "fallout," AC is also increasing its development of significant new commercial products. / This, too, is AC QUESTMANSHIP: the scientific quest for new ideas, methods, components and systems . . . to promote AC's many projects in guidance, navigation, control, detection and communication. / In the commercial field, AC is already producing communications systems, automotive controls and fuel controls for gas turbine engines. Some day they may even add such advanced projects as systems controls for "ground effect vehicles." According to Mr. B. H. Schwarze, AC Director of Commercial Engineering, "the proper application of scientific 'fallout' to commercial products leads to diversified career opportunities." / You may qualify for our specially selected staff . . . if you have a B.S., M.S. or Ph.D. in the electronics, scientific, electrical or mechanical fields, plus related experience. If you are a "seeker and solver," write the Director of Scientific and Professional Employment, Mr. Robert Allen, Oak Creek Plant, 7929 So. Howell Ave., Milwaukee, Wisc.

GUIDANCE / NAVIGATION / CONTROL / DETECTION / COMMUNICATIONS / **AC SPARK PLUG** The Electronics Division of General Motors

New *ElectriK Tel-O-Set*... needs in a single compact



everything an operator control station

This Honeywell electric control station meets all of your requirements for operator convenience.

One compact case houses *every* function the operator needs to supervise a control loop: indication of process variable and set point on the same scale; the controls needed to switch from automatic to manual; controls for manual control; and indication of valve position.

The *ElectriK Tel-O-Set* control station assures easier bumpless transfer than ever before available because there's no need to "line up" or "match" pointers. A null balance indicator eliminates guesswork, and the transfer doesn't have to be hurried since the valve remains under control during the transfer.

You can also order the controller with the proportional band, rate, and reset adjustments on the front of the panel conveniently located below the control station, or at the rear of the panel.

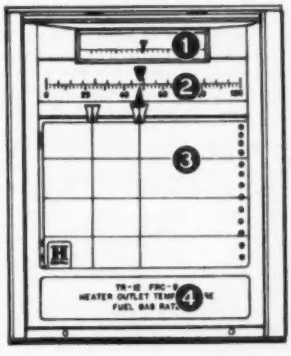
These are just a few of the features that make the new *ElectriK Tel-O-Set* control system an outstanding value. Your Honeywell engineer can give you complete details. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Fall River, Massachusetts.

75th YEAR — PIONEERING THE FUTURE

Honeywell

H HONEYWELL — First in Control — SINCE 1885



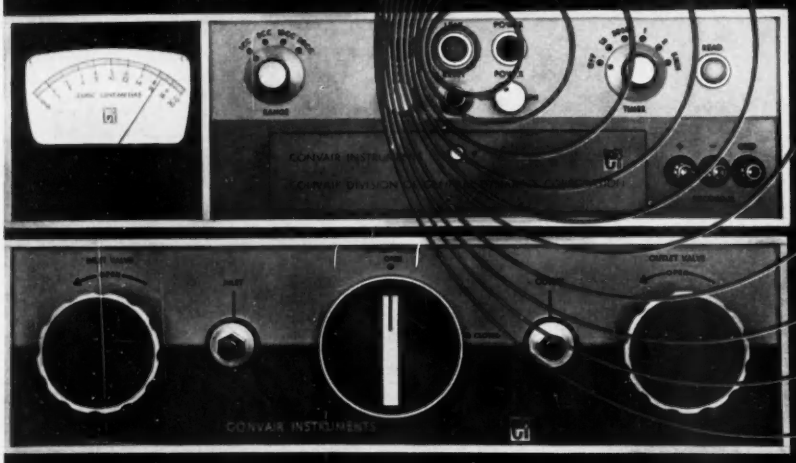
1. Valve position indicator continuously indicates controller output when on automatic control.

2. Set point index is conveniently located on same scale as process-variable pointer; you can see from a distance any deviation of variable from set point.

3. Rectilinear 4-inch calibrated chart is easy to read. At standard chart speed, four hours of recording is always visible. Unit has daily chart tear off or 30-day rewind. Both recorder and control station take the same 5½" x 6" panel cutout.

4. You get bumpless switching from automatic to manual control because you don't have to match pointers. In the balance position, the valve position indicator is part of a null circuit that compares controller output and manual output. When indicator reads 50%, both outputs are perfectly matched.

some leaks don't make drops



and the CI-LEAKMETER–NOW IN 3 MODELS,doesn't depend upon drop catching to measure hydraulic or fuel leakage!

A CI-LEAKMETER, *when installed in a line between a pressure source and the system or component under test, automatically detects and signals the existence of a leak. It automatically measures and indicates the amount of the leakage. A red light signals the presence of a leak –the amount of leakage is indicated on an electrical meter. The* LEAKMETER *incorporates a timer which can be set for test durations of 15 seconds to 5 minutes.*

Model No.	*Automatic Measurement Range*
Model 400	0.015cc to 80cc per minute
Model 410	0.0015cc to 8cc per minute
Model 420	0.00015cc to 0.8cc per minute

The LEAKMETER consists of an Hydraulic Assembly and an Electrical Assembly. These may be installed together, or at separate locations in the test area. Both are designed for rack mounting. Hydraulic connections are made by quick-disconnect fittings.

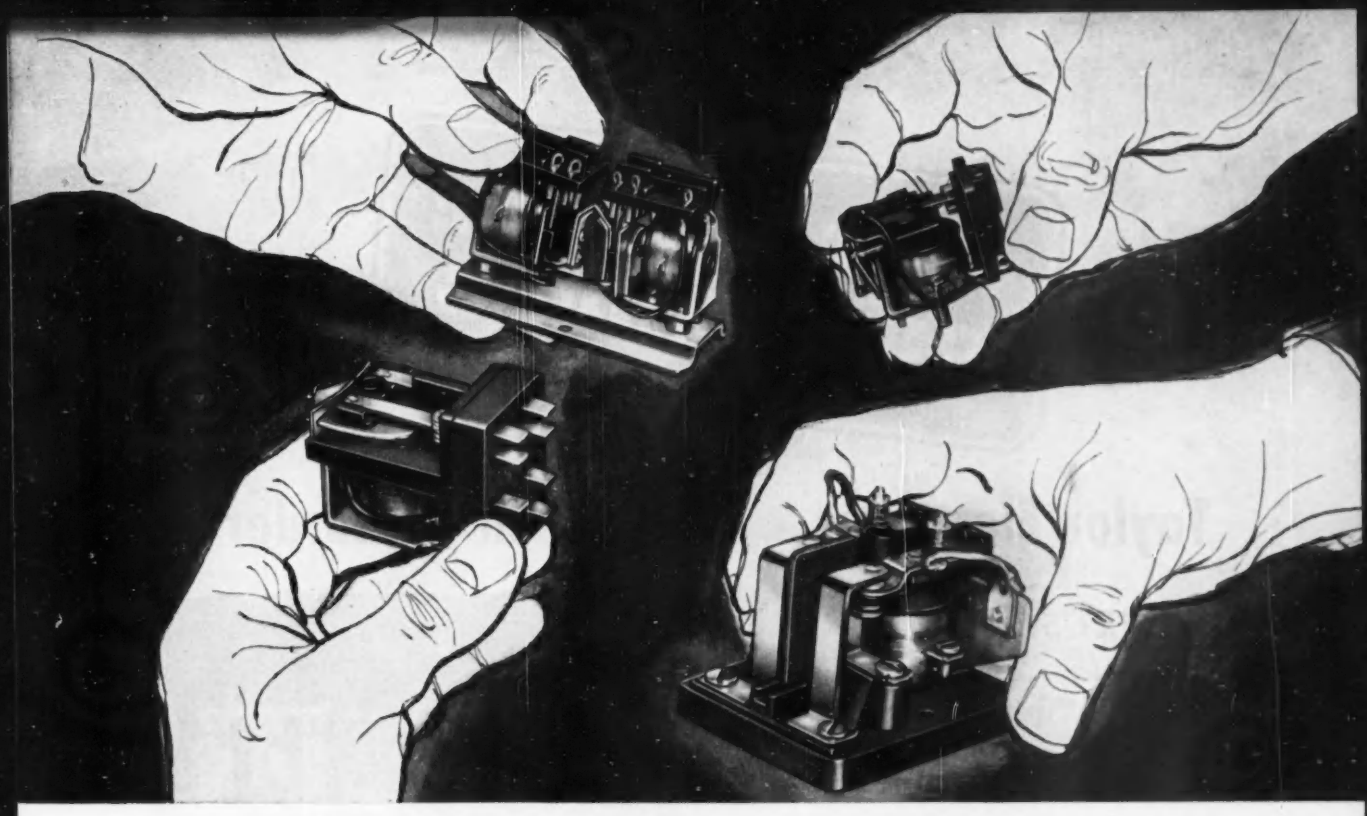
The LEAKMETER is compatible with all common hydraulic fluids and fuels. The item under test may be subjected to shock, vibration, or temperature, from which the LEAKMETER remains isolated. The instrument accommodates pressures to 5000 psi. Jacks are provided for recording or other readout.

For Complete Information–or to purchase a LEAKMETER *for Immediate Delivery, Write, Wire, or Phone:*

CONVAIR INSTRUMENTS / CONVAIR, A DIVISION OF GENERAL DYNAMICS CORPORATION

3595 Frontier Street, San Diego, California
ACademy 3-1614

ELECTROMECHANICAL AND MECHANICAL INSTRUMENTS;
AC AND DC MEASURING DEVICES, TRANSDUCERS.



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These important savings are yours when you order—from your Electronic Parts Distributor—P&B relays listed with Underwriters' Laboratories, Inc. and Canadian Standards Association:

SAVE TIME. You get fast, off-the-shelf delivery. Usually your order is shipped the day after it is received. And no waiting for U/L or CSA clearance . . . this has been done for you. Thus you get your project—and your product—off to a fast start!

SAVE MONEY. You save the cost of getting relays listed with U/L or CSA . . . and you need have no big investment in shelf inventory, either. Remember, you pay no premium over factory prices in quantities to 249.

More than 40 different standard P&B relays in 450 different coil voltages and contact arrangements are available from the leading Electronic Part Distributors in your area. For special applications, call your nearest P&B sales engineer.

PR Series

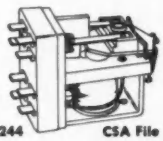
Type	Contact Arrangement*	Type	Contact Arrangement*
PR1AY	SPST-NO	PR5AY	SPDT
PR3AY	SPDT-NO-DM	PR7AY	DPST-NO
		PR11AY	DPDT

These relays are available in any of the following operating voltages: 6, 12, 24, 115, 230 volts 50/60 cycles AC.

Contacts are rated at: 25 amps, 115/230 V. AC 1 phase, 1 hp for 115/230 volt AC motors 1 phase.

*Read: NO normally open, NC normally closed, DB double break, DM double make.

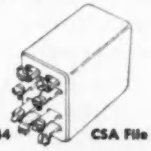
U/L File E22575 CSA File 15734



AB Series

U/L File E29244 CSA File 15734

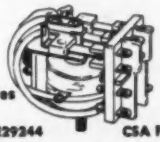
For appliance and general purpose operations requiring long life and quiet operation. Quick connect terminals. Screw terminal adapters also furnished with each relay. Contact arrangement: DPDT. Rated at 10 amps, 115 V., 5 amps, 230 AC non-inductive by U/L and CSA.



ABC Series

U/L File E29244 CSA File 15734

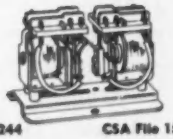
Medium duty power relay in dust cover. For small motors, industrial controls and similar applications. Contact arrangement: DPDT. Rated at 10 amps, 115 V., 5 amps, 230 AC non-inductive by U/L and CSA.



KA Series

U/L File E29244 CSA File 15734

Small, low cost, general purpose relay for handling automation work, small motors, solenoids, other relays. Contact arrangements: SPDT, DPDT and 3PDT. Rated at 5 amps, at 115 V., AC non-inductive by U/L and CSA.



KB Series

U/L File E29244 CSA File 15734

Compact latch relay ideal for memory work and overload applications. Operates on momentary impulse to either coil. Contact arrangements: 4PDT and 6PDT. Rated at 5 amps at 115 V., AC non-inductive by U/L and CSA.

POTTER & BRUMFIELD

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY, PRINCETON, INDIANA

IN CANADA: POTTER & BRUMFIELD CANADA LTD., GUELPH, ONTARIO

CIRCLE 73 ON READER SERVICE CARD

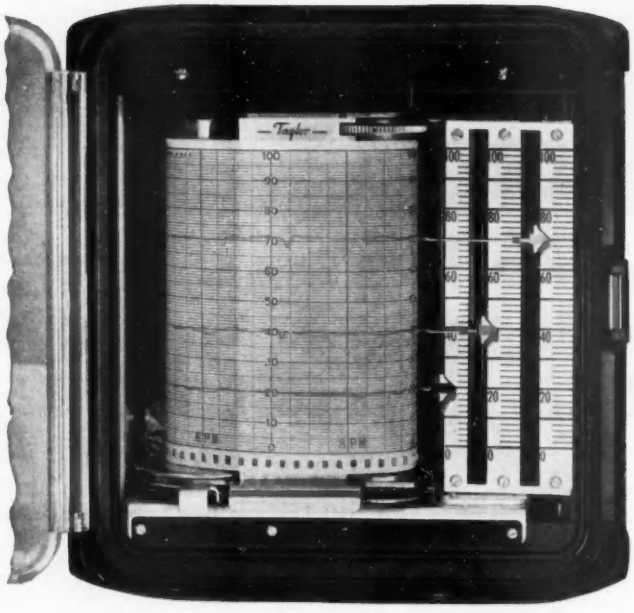
PERFORMANCE OUTSTANDING

Taylor Electronic 1, 2 or 3 Pen Recorder

HERE'S WHY:

- Takes any standard DC transmission input signals, e. g. 1-5 ma, 4-20 ma, 10-50 ma.
- Linear signal is recorded on rectilinear co-ordinates, reading left to right. Hundreds of standard charts.
- Uses DC voltages, minus 0.5 to +0.5, 0 to 1, 0.25 to 1.25 v. or any other DC voltage that can work into an impedance of 20,000 ohms per volt.
- Standard accuracy 0.5%. Optional, 0.25%. Accuracy unaffected by line voltage changes ±10%.
- Threshold sensitivity 0.1%.
- Speed of response excellent—full scale travel in less than ¾ second.
- Recorder pen can be quickly calibrated without even unplugging recorder slide.

All these advantages are made possible by use of an actual true 2-phase servo motor, coupled with a high-gain transistorized amplifier, standardized by Zener Diode voltage reference.



Available as a recording (700J) or indicating (701J-704R) control station, it also gives you these features: fastest response; bumpless capacitor gain switching; automatic stabilization during transfer; widest range of adjustments; multiple valve operation; elimination of overpeaking.

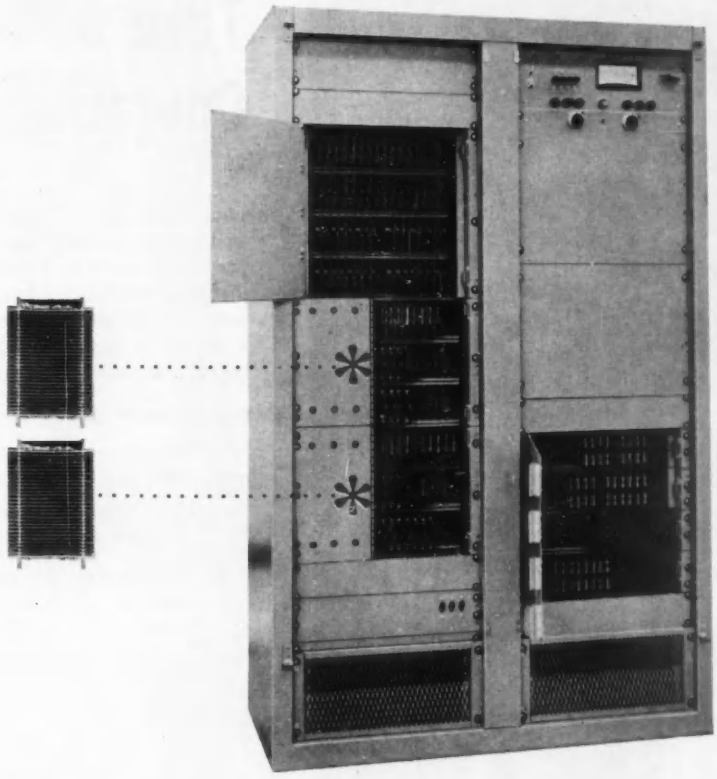
Team up the 700J or 701J with a Taylor electronic transmitter—for temperature, pressure or differential pressure.

Ask your Taylor Field Engineer for full details, or write for **Catalog 98335.** Taylor Instrument Companies, Rochester, N. Y., or Toronto, Ont.

Optional Features Available . . .

- Heavy-duty alarm contacts, 5 amps, 120 v. AC.
- 2-speed chart drive with flip of a switch. Any combination of 2, 4, 6, 9, 12, 15, 18 and 30″ per hr.; 1, 3 and 6″ per min.
- Retransmitting slide wire. (eg. for multiplication, square root extraction.)
- Will handle mv signals, 0-3 to 0-50, with 700T Pre-Amplifier.
- 24 hr. Adjust-O-Matic tear-off chart.

Taylor Instruments **MEAN ACCURACY FIRST**



HIGH SPEED CORE MEMORY WITH PROVED PERFORMANCE

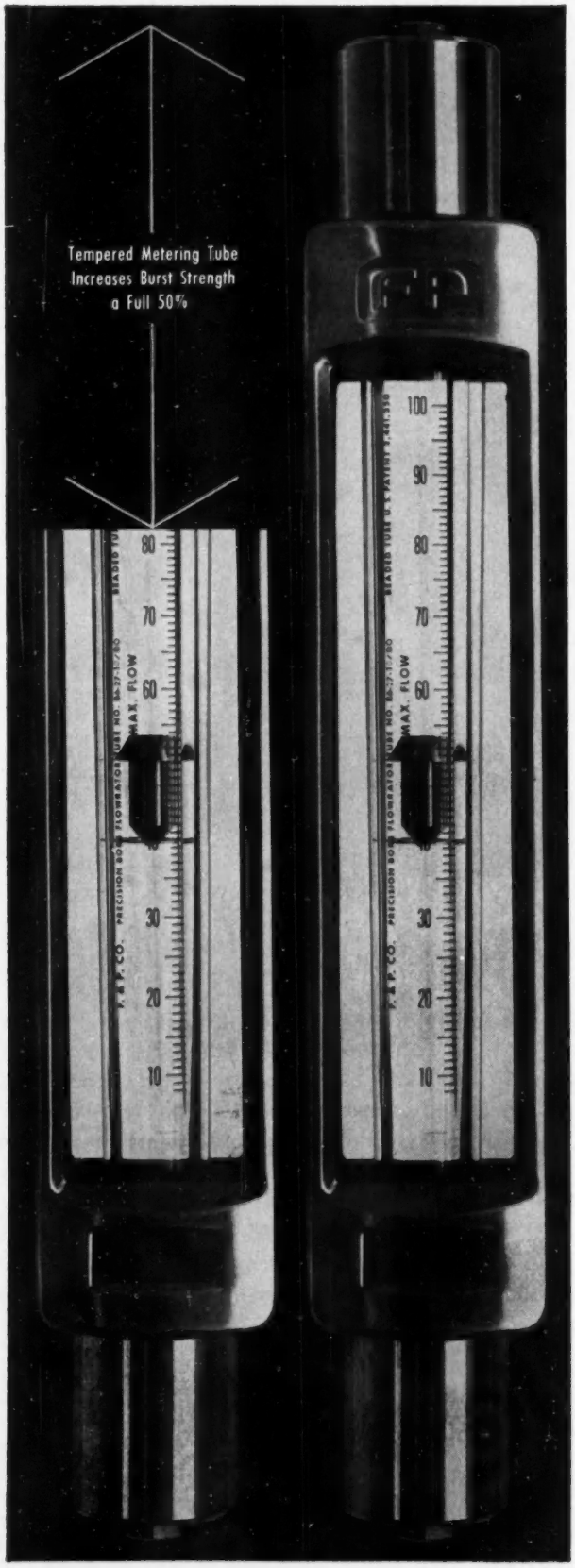
Low in cost and high in performance, Telemeter Magnetics Type RQ memories solve the problem of designing economical, high speed storage for computers and data processing systems. These reliable units, offering five microsecond cycle operation, are available on an off-the-shelf basis in a wide range of capacities and word lengths. ■ **A combination of economy, speed, and reliability** is achieved through modular design, utilization of advanced solid state circuits, and quantity production of memory building blocks such as **Digi-Pak and Drive-Pak modules.**

■ **Type RQ memories** are available in capacities from 512 to 16,384 words with word lengths from 8 to 56 bits. Larger capacities available on special order. ■ **Type RQ memories** now in service are establishing new records of reliability. This is a natural result of TMI's completely integrated engineering and production facilities, from ferrite material to complete memory systems, permitting lower manufacturing costs while achieving high performance. ■ **To discuss your needs** with a TMI applications engineer, write or call today

TELEMETER MAGNETICS, Inc.
P.O. Box 329, Culver City, California
offices and plant: 9937 Jefferson Blvd., Culver City, California

PIONEERS IN DEVELOPMENT AND MANUFACTURE OF CORE MEMORY PRODUCTS

CIRCLE 75 ON READER SERVICE CARD 75



New Rotameters Take 50% Higher Operating Pressures

Now, you can use glass tube rotameters where you've never dared use them before. New tempered glass metering tubes take up to 50% higher operating pressures. Install them with complete assurance on process lines that formerly required metal tube meters. And gain a desirable extra margin of safety *wherever* rotameters are used.

How F&P did it

This major advance in flowmetering art developed from two well known facts:

1. Glass has ten to twenty times more compressive strength than tensile strength.
2. Endwise pressure and uneven peripheral compression (as from a stuffing box) impart a substantial tensile component.

First F&P eliminated that tensile component by developing the unique O-ring "floating tube" seal introduced in the 2700 Series flowmeter.

Now, F&P has developed a special method of tempering the precision borosilicate metering tube that boosts compressive strength *without causing distortion!*

Be sure you get a tempered metering tube

Tempered borosilicate metering tubes are now being supplied as standard equipment with all Series 2700 flowmeters at no additional cost. But you *must* specify this make and series to enjoy the increased pressure rating.

Get complete information...Now

Write for your copy of Bulletin 91-123, "The Rotameter Sheds Its Limitations".

Fischer & Porter Company, 760 County Line Road, Warminster, Pennsylvania.

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Complete Process Instrumentation

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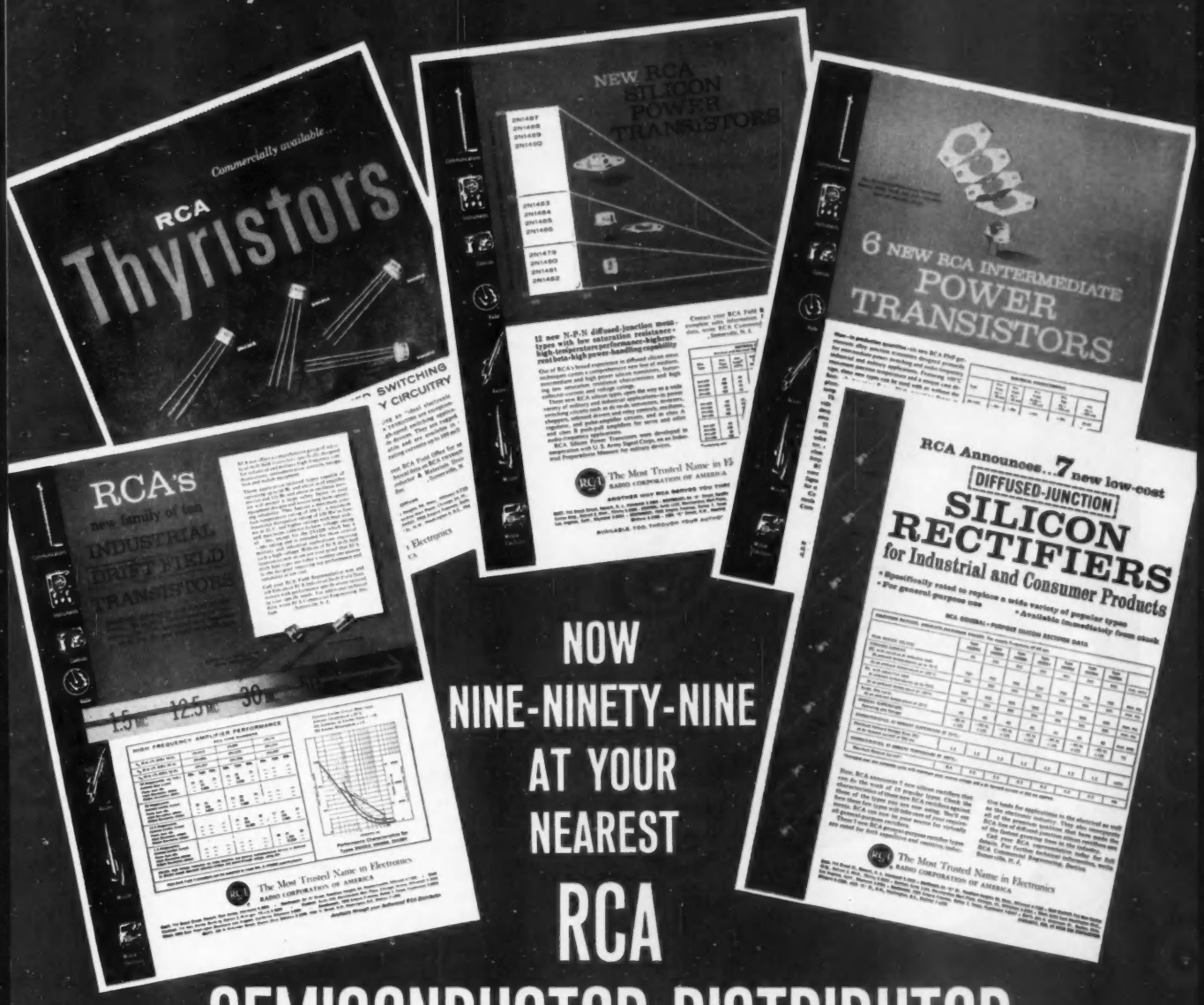

NOW NINE-NINETY-NINE AT YOUR NEAREST RCA SEMICONDUCTOR DISTRIBUTOR

RCA's *entire line* of Silicon and Germanium Transistors and Silicon Rectifiers is now as close as your telephone and can be obtained at factory low prices in quantities up to 999. The new "Drift Field" types...Thyristors, exciting new bi-stable switching transistors...the High Power, Intermediate Power and Medium Power Silicon Transistors featuring exceptionally low-saturation resistance...are just a few examples of the rapidly expanding line of RCA Semiconductor Products you can now quickly and conveniently order from your nearby RCA Semiconductor Distributor. And don't forget these *extra* benefits a call to your RCA SEMICONDUCTOR DISTRIBUTOR will bring to you:

- Prompt delivery of the latest RCA types for your evaluation
- Orders filled from factory-fresh stock
- Up-to-date, practical product information
- Valuable technical assistance when you need it
- "One-stop" service on your orders
- Specialists who understand your problems and your electronic needs

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RCA The Most Trusted Name in Electronics
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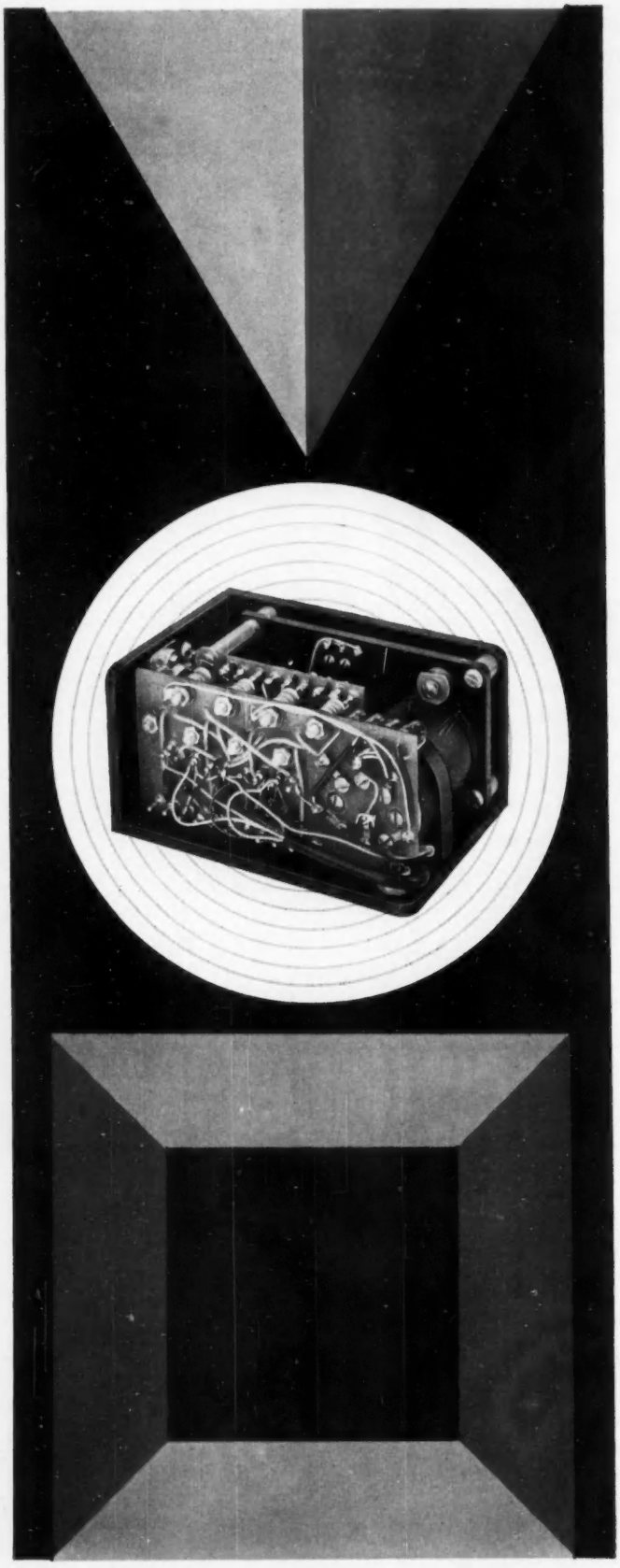
Stitch in Time



ADVANCING THE ART OF
LOGICAL DESIGN

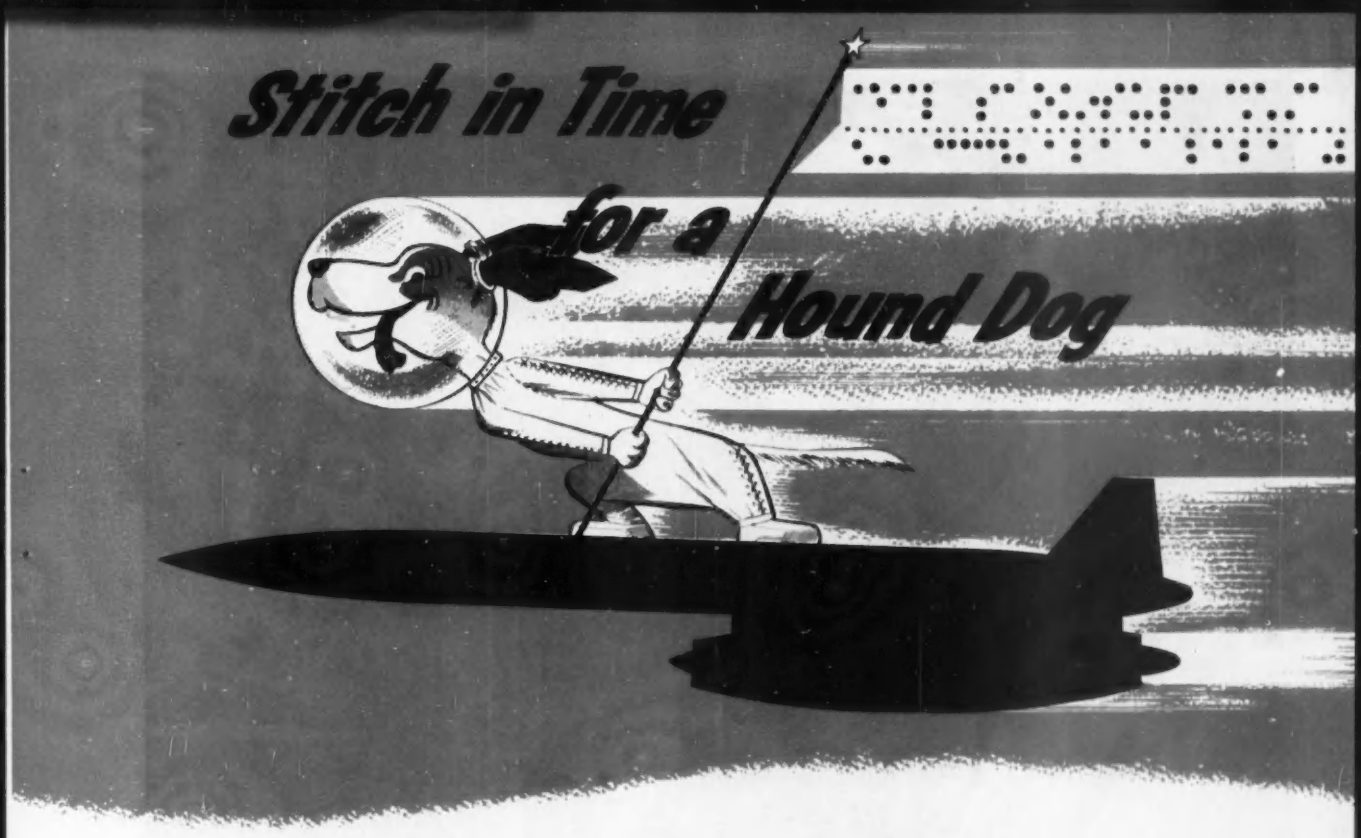
The basic simplicity of subsystems developed by American Electronics is a notable result of Logical Design achievements at the Instrument Division. Maximum reliability and efficiency—at minimum cost—are achieved through advanced circuitry and skilled packaging of components. Another result of this approach has been the substantial reduction in system weight and size while maintaining rigid performance and accuracy standards.

Combining years of experience in precision component manufacturing with creative subsystem engineering, American Electronics offers a record of proven capability, serving many of the nation's leaders in space and flight control.

Shown left is an AEI Digital Servo System used by a leading missile manufacturer to tune a radar klystron to a precise frequency. This compact system embodies an error-sensing device, an amplifier-logic circuit and a pulse motor with special design features offering exceptionally long life and high reliability.

American Electronics subsystem engineers have applied Logical Design principles to solve many space age problems. Analysis of your problems is invited. Please write for detailed information.

AMERICAN ELECTRONICS, INC.
INSTRUMENT DIVISION
9503 WEST JEFFERSON BLVD., CULVER CITY, CALIF.
UPTON 0-5581



New Tally Tape Console cuts punched tape preparation time by 600% on Hound Dog missile

Last fall, the first production model of the new Tally Tape Console was delivered to North American Aviation's Missile Division to speed the preparation of punched paper tapes. The tapes in turn program both production and preflight missile checkout systems on SAC's Hound Dog missile.

Before the Tally Tape Console was installed North American Missile Division engineers took 30 hours to make and absolutely verify a 400-foot programming tape. To make and absolutely verify a duplicate copy of the tape required an additional 75 minutes.

The Results

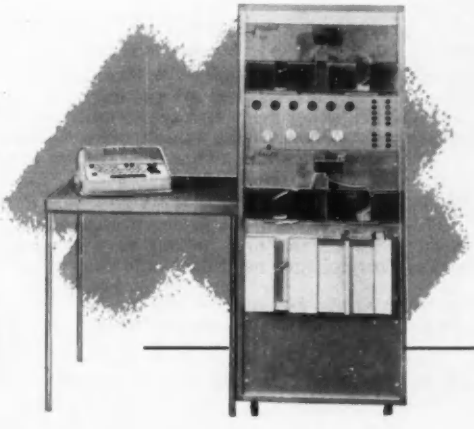
Now, North American Missile Division engineers using the new Tally Model 150 Tape Preparation and Editing Console make 400-foot tapes in three to four hours. Duplicate tapes are made in only 37 minutes. And Tally tapes are *guaranteed* error free.

Tally/Seattle is pleased to have played a significant role in North American's pace setting GAM-77 program which took only thirty months from design to flight of production models by SAC crews.

Tally's Tape Console simplifies and automates punched paper tape production

It features tape-to-tape duplication and verification at 60 characters per second. A keyboard visual display and shift register reduces error and operator fatigue in both punching and verifying modes. Tape corrections can be made without overpunching or splicing.

The Tally Tape Console is another new product from a creative engineering team specializing in punched paper tape technology. Your nearby Tally engineering representative can provide you with complete technical information on the Tally Tape Console or you may write directly to Dept. 21



TALLY

REGISTER CORPORATION

1310 Mercer Street
Seattle, Washington
Phone: MAin 4-0760

CIRCLE 79 ON READER SERVICE CARD

Who Discovers the Discoverers?

"A professor can never better distinguish himself in his work than by encouraging a clever pupil, for the true discoverers are among them, as comets amongst the stars." CARL LINNAEUS

Somewhere in this mighty land of ours, a gifted youth is learning to see the light of tomorrow. Somewhere, in a college classroom or laboratory, a dedicated teacher is gently leading genius toward goals of lofty attainment. Somewhere the mind of a future discoverer—in science, engineering, government, or the arts—is being trained to transcend the commonplace.

Our nation has been richly rewarded by the quality of thought nurtured in our colleges and universities. The caliber of learning generated there has been responsible in no small part for our American way of life. To our college teachers, the selfless men and women who inspire our priceless human resources, we owe more than we will ever be able to repay.

Yet how are we actually treating these dedicated people? Today low salaries are not only driving gifted teachers into other fields, but are steadily reducing the number of qualified people who choose college teaching as a career. At the same time, classrooms are beginning to get overcrowded. In the face of this, college applications are expected to double by 1967.

This is a severe threat to our system of education, to our way of life, even to our very existence as a nation. Our colleges need help—and they need it now!

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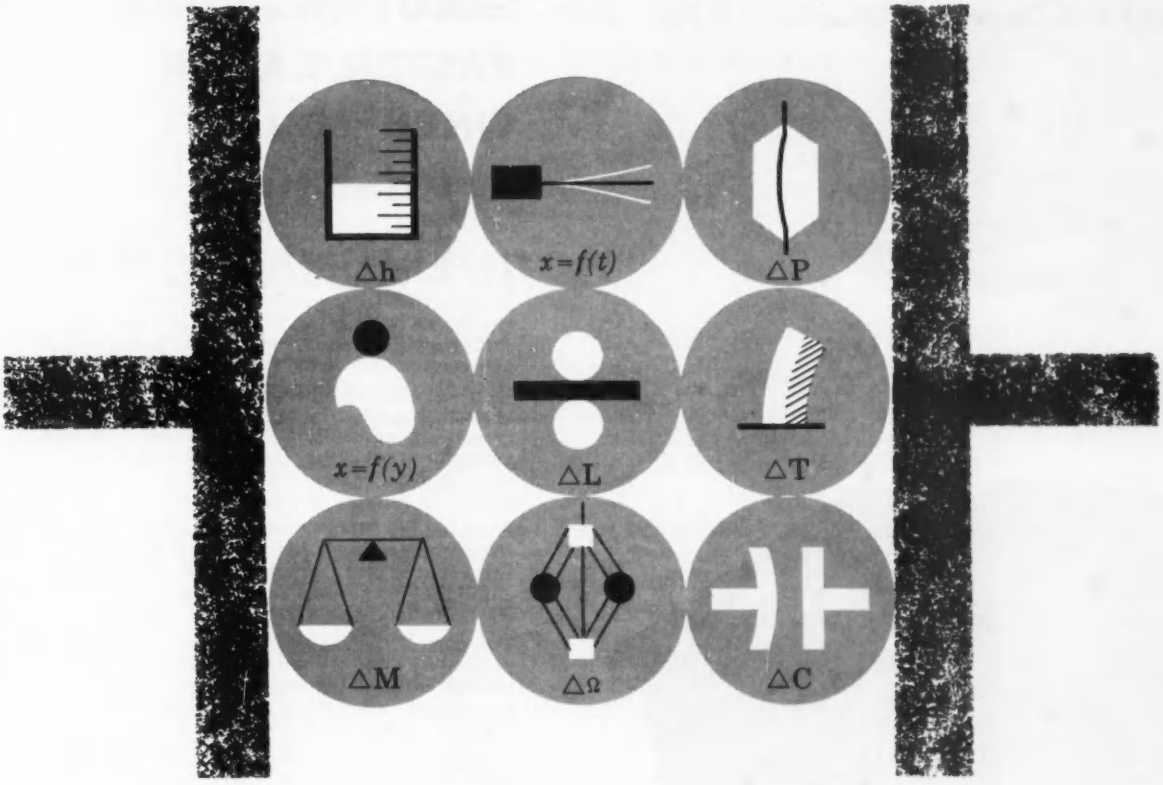

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This one instrument lets you measure—without contact—*any* variable you can convert to a change in capacitance. And lets you do it more accurately and at less cost than has ever before been possible.

Decker's new Delta Unit 904-1 accepts capacitance changes as small as 1 mmf, responds with analog output voltages as large as 30 Vdc which indicate direction as well as magnitude of change.

You simply plug the unit into a 60 cy. 115 v. supply and connect the probe to any simply constructed capacitance sensor that suits your special needs. Everything else you need is built right in . . . including an easily read meter that may be bypassed if necessary to facilitate external recording, display, or control.

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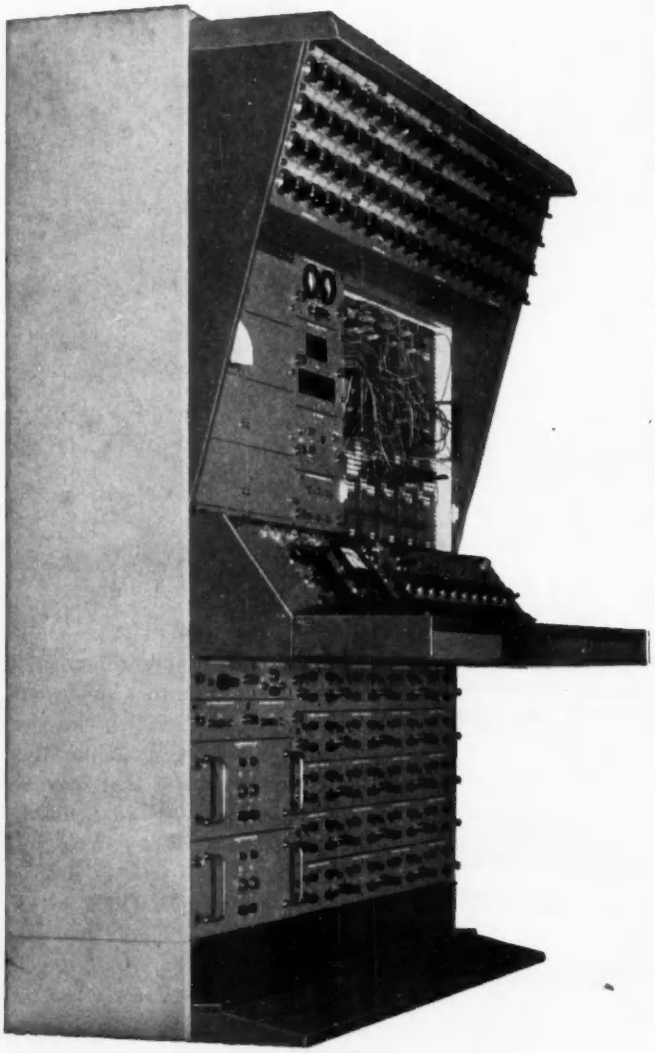

You can expect, (and be sure you'll get) the utmost in working accuracy and fine construction from every PACE computer. It's simple, we build more in – you get more out. But you will have to actually sit at the console to appreciate some of its very finest points.

Take our control panel for instance. *Every* important control is within easy reach from a sitting position. Including *all* coefficient potentiometers. Quick adjustments are easy, and the panels are sloped for restful operation through the very longest day.

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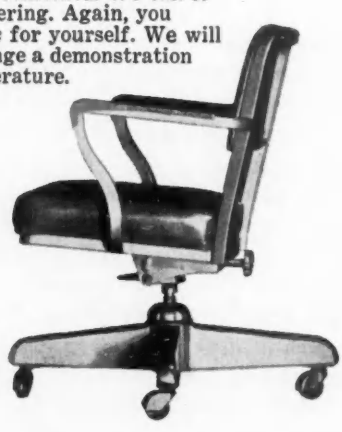
Dept. CB.



EAI ELECTRONIC ASSOCIATES, INC. *Long Branch, New Jersey*

Crisis in Exports

Precision instrument makers can expect as much as a 25 to 50 percent boost in export sales this year as a result of the government's new overseas sales promotion program. This will come on top of a record 1959 instrument export year in which the industry exported $279 million worth of instruments to 130 countries.

Dim view

But the overall U.S. export picture is still not bright. Although 1958's surplus of imports over exports (CtE, August 1959, p. 61) was corrected last year, the balance in favor of exports is not large. Last year the U.S. exported $16.2 billion worth of goods while importing $15.3 billion worth.

Dept. of Commerce officials feel that most product lines will enjoy good export business this year. But the reason can be traced to some cyclical effects, rather than to a healthy trend of selling more U.S. goods abroad. And what really worries government planners is what is likely to happen next year if some drastic improvement isn't injected into the export situation.

Because the cyclical factors that are helping 1960 exports will dissolve this year, next year may be the worse export year the U.S. has had recently. That's why the government has launched a strong program to help sell U.S. exports abroad.

Part of this program is a series of Dept. of Commerce-industry group meetings to discuss export obstacles. Last month representatives of the instrument industry met with Commerce economists and spelled out some suggestions for boosting instrument sales.

Roadblocks

Biggest roadblocks to instrument exports, said the industry representatives, are foreign import licensing regulations, tariff curbs, currency exchange restrictions, special taxes, and product classification problems. Industry spokesmen particularly urged the government to bargain for lower foreign import tariffs and other barriers at next fall's meeting of the General Agreement on Tariffs and Trade (GATT). And U.S. strategic trade control officials were urged to approve more licenses for the export of scientific and precision instruments to Communist-bloc nations.

This last is one of the touchiest problems in the export field. There is strong Congressional feeling about letting the bars down on exports to the Communist bloc. Yet, industry spokesmen complain, competition from Western European and Japanese instrument makers has fewer governmental security restrictions than U.S. exporters. Any easing on such U.S. restrictions would have to wait until officials have had a chance to assess the results of the summit meeting between the Soviet Union and the West.

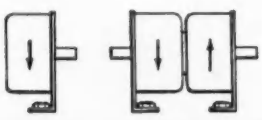
Shooting for $2 billion

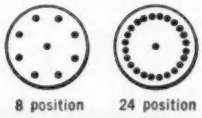
Dept. of Commerce thinks its sales promotion program will give the export business the stimulant it needs to get it over the crisis next year. If, say Commerce planners, the U.S. can increase its surplus of exports over imports to $2 billion next year, the export situation will be safe for several years to come.

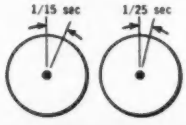
State Dept. officials who are negotiating the relaxation of foreign regulations are not so optimistic. They have to face the continued

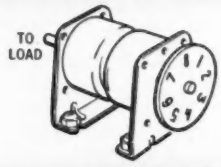
New Ledex Digimotor®

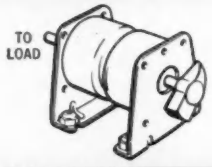
IS MAJOR ADVANCE IN STEPPING MOTOR FIELD

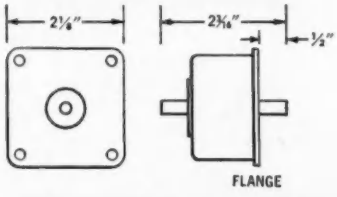












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New Ledex *Digimotor Switches* are rotary selector switches with all advantages of the Digimotor drive plus other special features.

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Other Ledex products include Rotary Solenoid, Rotary Solenoid Selector Switch, Hermetically Sealed Selector Switch, and *Syncramental* Stepping Motor. Mechanical applications include actuation of valves, vanes, printers, shafts. Switching applications include circuit selecting, stepping, counting, programming and sequencing. Write for literature, mentioning application, to Ledex, Inc. (formerly G. H. Leland, Inc.), Dayton 2, Ohio; Marsland Engineering, Ltd., Kitchener, Ont.; NSF Ltd., 31 Alfred Place, London, Eng.; NSF GmbH, Nurnberg, Germany.

intense feelings of nationalism around the world and the desires of a lot of countries to develop their own manufacturing industries.

Most consumer goods industries are plagued with the problem of growing foreign competition, particularly from European Common Market countries and Japan. The ECM has tended to slow down overall U.S. exports of such merchandise, although it has had a stimulating effect on instrument and control exports. There is a rush to build new plants in the ECM area and the rush of construction is keeping U.S. instrument makers busy and happy.

It is this boom in new facilities that makes 1960 look so good for instrument exports. Dept. of Commerce expects precision instrument exports to hit $400 million this year.

Customers . . .

A breakdown of last year's exports shows where these instruments are going. Nine countries represent the leading markets—Canada, Japan, Venezuela, Italy, France, Mexico, West Germany, Brazil, and the United Kingdom. Canada takes about one-third of the total. But observers have noted the start of a shift in foreign investment from Canada to European Common Market countries. Direct investment in Europe was up a whopping 151 percent from 1958 to $434 million last year. And the shift is likely to be followed by new plant capacity and instrument sales.

. . . and what they buy

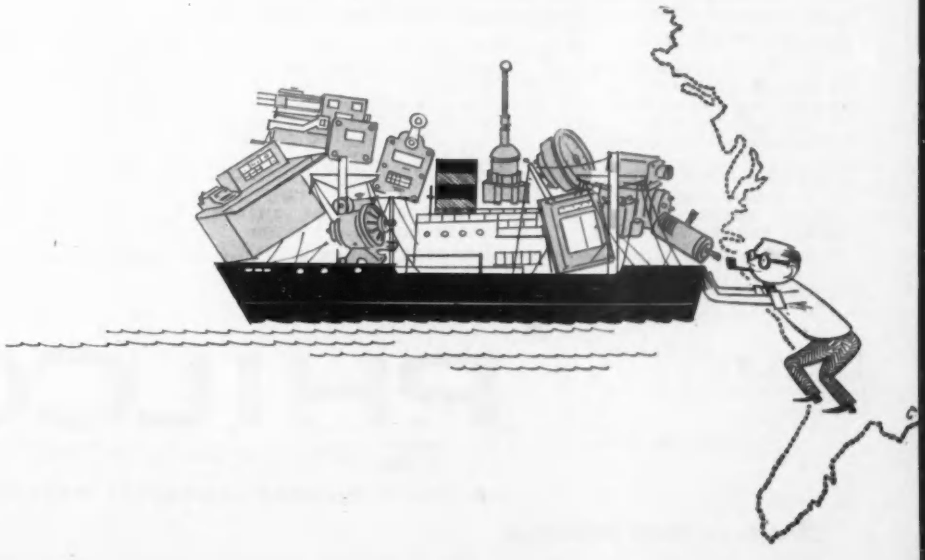
Of the $279 million in instruments exported last year—one twelfth of the estimated $4 billion U.S. instrument sales—$231 million were industrial and technical instruments. Two groups each accounted for $67 million. They were indicating, recording, and controlling instruments and electronic detection, navigation, and aircraft instruments. Exports of technical measuring instruments totaled $58 million; exports of electrical-electronic instruments added up to $39 million.

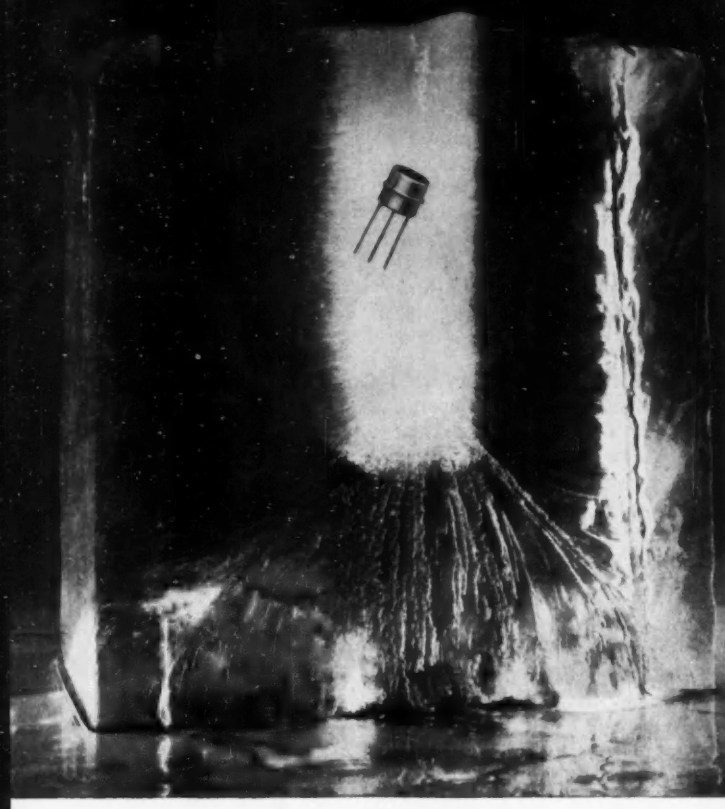
Black cloud

What happens if the Dept. of Commerce's program for export promotion doesn't live up to expectations? The possibilities are ominous. Already faced with a serious gold flow problem (the U.S. has had to ship gold for several years after being continually a receiver of such payments), government monetary experts have found their freedom of action substantially curtailed. The situation makes it difficult to finance government loans like bonds because it raises interest rates. So one of the first steps to be taken—and pressure is already being exerted for such action—will be the curtailment of foreign investment.

That would restrict U.S. makers from building new instrument plants abroad to capitalize on the common markets (for a new one see page 183). And it would curtail construction plans abroad; this would be reflected in depressed instrument sales.

This year's export figures will be must reading for executives in the instrument industry.





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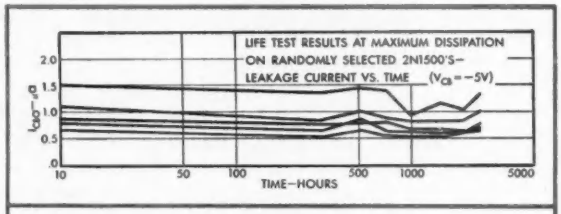
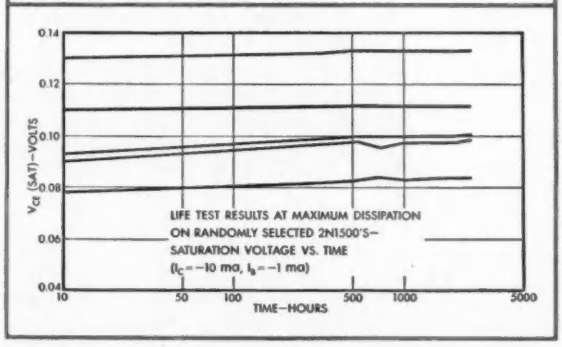
Philco Micro Alloy Diffused-base Transistors (MADT) are now manufactured with cadmium junctions. This is another major advancement in transistor engineering . . . developed and offered exclusively by Philco! The higher thermal conductivity of cadmium insures cooler-running junctions for any given power dissipation . . . providing far greater transistor reliability and an extra margin of safety. It permits rating high-frequency germanium transistors for 100°C maximum junction temperature. Cadmium permits higher power dissipation, higher storage temperature, and improved capacity to withstand temporary overload. In addition to these advantages of cadmium, Philco MADT transistors have retained all the proven superb characteristics of the famous MADT line:

- low collector capacitance
- low saturation voltage
- high beta and excellent beta linearity with temperature and current
- excellent high-frequency response
- low hole storage time
- excellent temperature stability
- low noise figure





The Philco MADT line, now with cadmium junctions, include:

AMPLIFIERS			SWITCHES		
2N502	2N502A	2N503	2N501	2N501A	2N1204
2N588	2N1158	2N1158A	2N1495	2N1496	2N1500

2N1494

For complete specifications and applications data, write Dept. CE-660.

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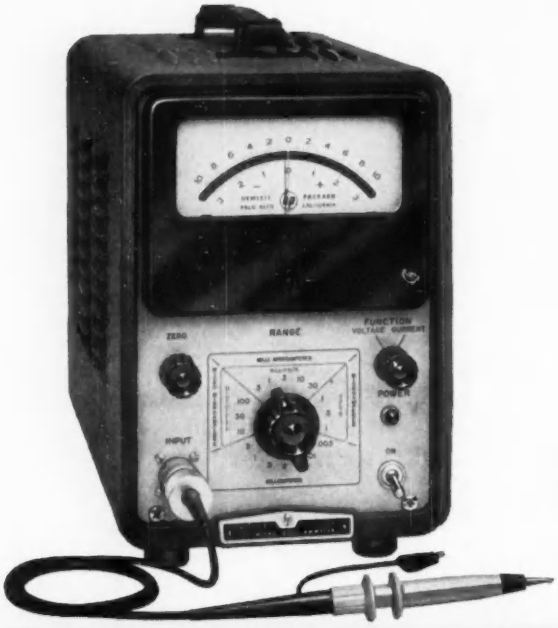
Now you've got to select the system components. Freeze their specs before you've found out what components are available, and you're dead. If you neglect products that have just come on the market, you'll risk having a system that's obsolete before it's completed. Go to products that have not yet been evaluated, at the other extreme, and you may wind up with a system that is exciting but won't work. What do you do now? Shudder at the 15 feet of manufacturer's catalogs that's spilling off your bookcase? Dig out all the buyer's guides you can find, only to discover that the information in the bulk of them is not verified? Call in vendors to get some advice, why not, it's free—or is it? Scrounge copies of defense agency product surveys? Scan technical publications for product surveys and find that all too few are not results of careful evaluation?

At about this time you'd be very much attracted to PERCOS—Performance Coding System of devices for measurement and control. It is a digital system of classifying manufacturer's data on the types of components listed at the left of this page; their forms of input and output (i. e., mechanical, magnetic, acoustical, etc.); and the orders of magnitude of their precision, stability of calibration, rate of performance, mean shelf life, mean time to failure, mean repair time, cost, availability, and space occupied. With it the automatic-systems engineer might isolate the myriad satisfactory components for close screening. IRE's Committee 10 on Industrial Electronics has cooperated with the author, E. A. Keller of Motorola, in creating it.

It sounds like the answer to your prayer, but you'd best get a copy and study it critically before embracing it. It's no panacea; its appealing logic can never replace your judgment. We are not at all certain that all manufacturers would furnish data of the variety and depth required. An independent operator of a subscription service would have to process the data. That's expensive; how much would you pay for it? If it seems promising to you, write us for a copy of the complete description. Chairman Eugene Mittelmann of the committee has asked our aid in obtaining comments on whether it would perk.

W. E. Vannah



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MICROVOLT-AMPLIFIER

Voltages: Pos. and neg. 10 μv to 1 v full scale. 11 ranges, 1-3-10 sequence.

Current: Pos. and neg. 10 μμa to 3 ma full scale. 18 ranges, 1-3-10 sequence.

Input Impedance: 1 megohm on voltage ranges, 1 megohm to 0.33 ohms on current ranges.

Accuracy: ±3% full scale.

AMPLIFIER:

Frequency Range: dc to 0.2 cps

Gain: 100,000 maximum

Output: 0 to 1 v, adjustable

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The Acceleration Switching Valve Still Has Advantages

Still a too little-used newcomer among electrohydraulic servovalves almost five years after its invention, the acceleration switching valve possesses a unique combination of reliability, resolution, and performance—especially at high temperatures—and ought to be considered seriously by more system engineers. Here are some practical considerations based on real experience with the switching valve, plus sufficient theoretical exposition to give a good fundamental understanding of its behavior.

MORTON E. MOORE
Autonetics Div., North American Aviation, Inc.

John G. Chubbuck invented the acceleration switching servovalve and described it originally in an article entitled "Are High Performance and Low Cost Compatible in Hydraulic Servos?" (CONTROL ENGINEERING, March '57, pp. 98-103). Since that time much development effort has been expended on these valves and at least two manufacturers have offered them for sale. So far costs are approximately equal to any other type of servovalve, but there has been no widespread, high volume application which would enable manufacturers to achieve production economies comparable with those of other types. On the basis of performance for dollar investment, however, the acceleration switching servo outstrips its rivals even at present prices. This follows from these advantages:

- Better reliability by an order of magnitude
- Almost infinite resolution with high linearity at the null point
- Maximum system stiffness
- High dynamic performance
- The only valve that operates satisfactorily at high temperatures

These advantages are due directly to the valve's unique mode of operation. Figure 1 shows the acceleration switching valve in cross section. A very crude switching valve can be made from any conventional dual nozzle flow control valve simply by removing the centering springs from the ends of the spool. Without the springs the spool will move in a positive or negative direction so long as there is a positive or negative command signal to the valve's torque motor. Spool position and thus flow are therefore proportional to the integral of the input signal. Valve output is controlled by causing the input signal to time-modulate an asymmetrical square wave. Chubbuck's article included a practical electronic driver circuit.

The amplitude of the input square wave is sufficient to saturate the torque motor in either direction and cause the flapper to alternately close the first stage nozzles. Thus, nearly full supply pressure is switched from end to end of the second stage spool at the frequency of the square wave. (Entirely successful operation has been obtained with switching frequencies up to 450 cps.) When the positive-going and the negative-going portions of the square wave cycle are of equal length—that is, balanced—the spool will "dither" about a nominal position at the square wave frequency, since it can move only a very small distance during a half-cycle. An input

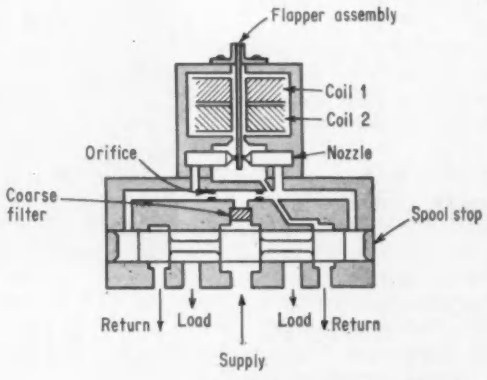


FIG. 1. Cross section of typical acceleration switching valve.

signal unbalances the square wave so that an average force differential appears across the spool, which will then move as long as the input signal persists. So even with the modulated square wave input the acceleration switching servovalve integrates.

Switching improves performance

The performance of conventional proportional valves deteriorates with use. The four principal causes of this deterioration are reduced by the switching technique. In a proportional valve:

1. Dirt builds up between the flapper and nozzles, causing gradual bias shifts, erratic operation, and eventual failure.
2. The linearity required of the magnetic circuit in the torque motor is gradually spoiled by magnetic particles, altering valve characteristics and possibly causing outright failure.
3. Silt accumulation at the metering edges of the valve spool-body combination increases spool friction forces, decreases resolution, and possibly causes outright failure.
4. Rounding-off of metering edges by a mere 0.0002 or 0.0003 in. by abrasive contaminants markedly increases leakage flow and reduces performance.

Switching partially or completely eliminates these four problems as follows:

1. The physical contact of the flapper with both nozzles during each cycle of the switching frequency prevents any dirt accumulation.
2. The switching mode of operation reduces the torque motor task from that of accurately positioning the flapper between the nozzles to that of simply assuring that it moves quickly from one nozzle to the other. The transit time should be minimized, and a heavy-duty torque motor can help. The switching also minimizes the bias shift with temperature that is caused by differential expansion and thermoelastic effects, and it is responsible for at least half the valve's success at high temperatures.
3. Since 80 to 90 percent of supply pressure is available to move the spool (a minimum of 100 lb force for a 0.250-in. diam spool and a 3,000-psi supply), sticking of the spool is eliminated. The natural spool dither effectively prevents silting in the first place.
4. Larger values of spool displacement are generally used for full flow output in switching valves, which reduces the importance of wear at the metering edges though it also reduces second stage gain.

Operating experience at high temperatures has shown that a varnish-like deposit gradually bakes on between the body and spool and greatly increases spool friction. Acceleration switching servovalves have developed nearly 10 lb breakaway friction force from this cause on a 0.250 in. diam spool yet have performed entirely normally and acceptably (10 pounds friction and all) until the system pressure was lowered below 750 psi. A proportional valve under such conditions would be totally inoperative.

Switching valve performance

From a purely technical standpoint the switching valve has a transfer function of the form $K\,\tau_v/(\tau_v\,s + 1)$. However, τ_v is large (values of 0.5 to 0.15 sec are common) and thus the valve is essentially an integrator in its working range. The presence of a time constant at all is due to small residual flow forces on the spool. In application these forces are not important: it is virtually impossible to find an input signal so small that a corresponding change in valve output cannot be measured. Further this excellent resolution does not decrease with continued use of the switching valve.

High system stiffness is a direct consequence of the integrating characteristic of the valve. On a Bode plot the valve itself crosses the zero db line at 0.16 cps or 1 rad per sec, neglecting for the moment the nominal value of τ_v. Connected to an actuator the combination crosses the zero db line at the same point with a slope of 12 db per octave.

SWITCHING SERVO AND ITS RESPONSE

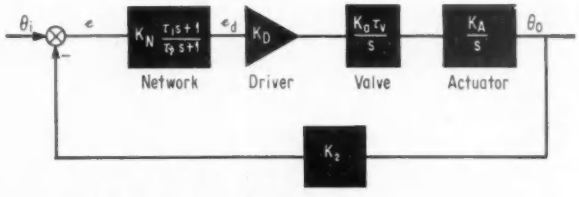


FIG. 2. Typical position servo using acceleration switching valve.

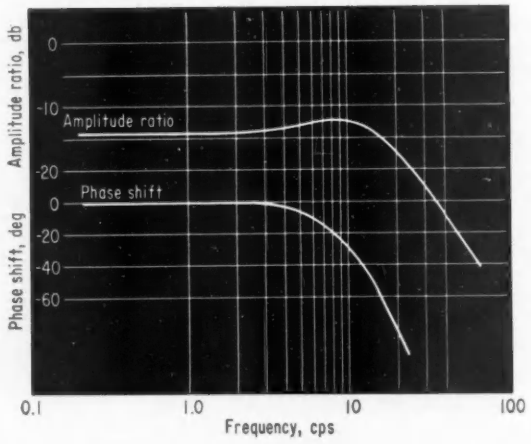


FIG. 3. Response of acceleration switching servo in Figure 1 with gain constants given in the text.

Thus a 16-cps servo represents two decades or 80 db of excess gain at 1 rad per sec. If the time constant of the valve is equivalent to a corner frequency of 1 cps ($\tau_v = 0.15$), this same servo will yield 64 db excess gain at 1 rad per sec. This excess gain is responsible for the high system stiffness. In other words, the pressure gain of the acceleration switching valve is much higher than that of the proportional valve.

High dynamic performance was listed as one of the advantages of the acceleration switching servo. This may not be clear at first glance since the valve's frequency response is anything but flat. It is generally true, however, since adequate gain may be realized by suitably sizing the valve to the system without adding gain in the electronic portion of the system. Further, the response curves published for proportional valves frequently are obtained by blocking the actuator ports and substituting a differential pressure transducer for the actuator. Frequency response looks good under such test conditions because the valve spool must move only very slightly to cause full pressure change. But in actual applications the spool must move an appreciable distance, and its dynamic response is limited by the rate of oil flow to the spool through the feed orifices. Also since the flapper never fully caps the nozzles, the maximum gain of the first stage of a proportional valve is somewhat lower than the first stage gain of an acceleration switching valve. In real applications, therefore, the proportional valve does not deliver the flat response so often associated with it, and in the final analysis there may not be very much difference between the proportional and the switching valve when driven to maximum output.

Calculating servo response

Consider now the acceleration switching servo in Figure 1. Assuming reasonable values of gain constants, as follows:

$K_N = 0.15$
$K_D = 0.50$ percent modulation/100 per volt
$K_a = 500$ cu in. per sec per sec
$K_A = 3.0$ in. stroke per cu in. oil flow
$K_2 = 25$ volts per in.

The open-loop gain is thus 2,815. The response of this servo is plotted in Figure 3. It is down 0 db at 15 cps. Values of K_a of 2,500 or more are readily realizable, and values of K_2 of 100 volts per in. are not unreasonable. Therefore the response of the system could be extended to over 70 cps. Further, this can be done without adding gain in the electronic part of the circuit.

Figure 4 shows the performance of the servo of Figure 2. Certain liberties have been taken to emphasize the behavior. In practice the switching activity is small in relation to the spool motion when the driving frequency is quite high as shown.

The valve spool moves with an effective velocity

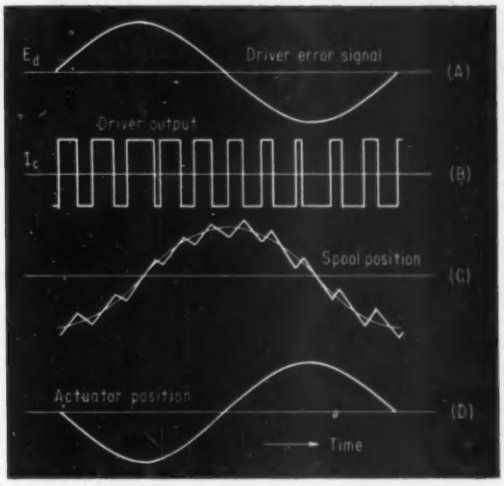


FIG. 4. Dynamic behavior of four parameters in switching servo. Note double integration from error signal to spool position to actuator position.

$V = V_s M$, where V_s is the maximum spool velocity and M is the modulation factor $(\tau_1 - \tau_2)/(\tau_1 + \tau_2)$. The maximum spool velocity is determined by the size of the in-bleed orifices, the system pressure, and to some extent the nozzle size and gap. If the maximum spool velocity V_s is multiplied by the flow gain of the valve, which is equal to Q/X_s cu in. per sec flow for X in. spool displacement, then the result is a figure K_a, the acceleration switching gain of the valve in cu in. per sec. This figure represents the maximum rate at which flow can be varied by the valve and is equivalent to a maximum possible actuator acceleration. Thus the term acceleration switching derives from the switching mode of operation of the first stage torque motor and the fact that the actuator acceleration is proportional to driver error signal.

The closed-loop transfer function of the servo in Figure 2 is:

$$\frac{\theta_o}{\theta_i} = \frac{K_N K_D K_a K_A(\tau_1 s + 1)}{K_N K_D K_a K_A(\tau_1 s + 1) + s^2 + \tau_2 s^3}$$

$$= \frac{K_1(\tau_1 s + 1)}{\tau_2 s^3 + s^2 + K_1 K_2 \tau_1 s + K_1 K_2}$$

Figure 5 shows a root locus plot of the servo. The system contains two excess poles, neglecting higher order effects. Figure 6 shows the effect on the root locus of varying the lead network gain constant K_N. Note that as a positional servo the acceleration switching system exhibits essentially constant damping over a wide range of gain values, and as system gain is constantly changing with load in almost all cases, this is a most welcome feature. In fact the servo may be designed to give near critical damping over a wide range of gain values, as indicated by

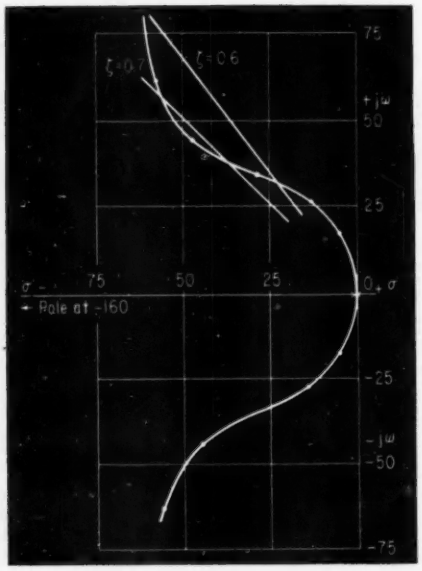
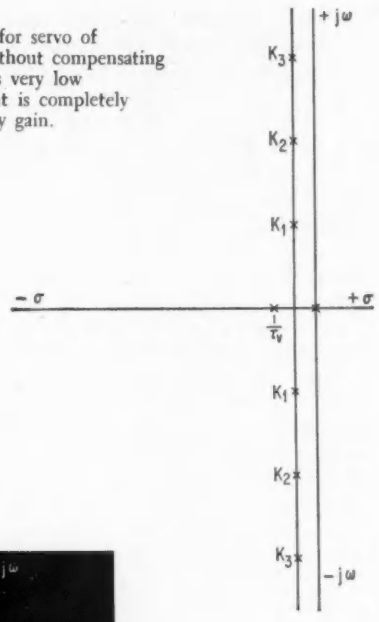


FIG. 5. Root locus plot of servo in Figure 1.

FIG. 7. Root locus for servo of Figure 1 without compensating network has very low damping but is completely stable at any gain.



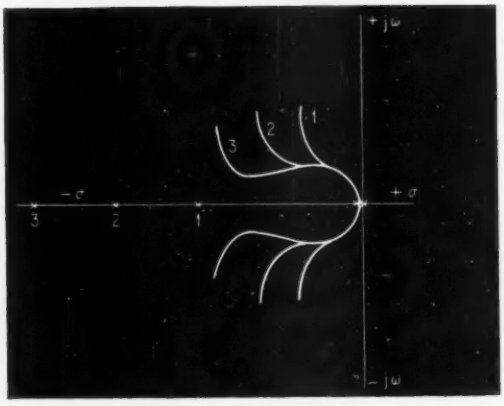


FIG. 6. Effect on plot in Figure 5 of varying lead network gain constant K_N.

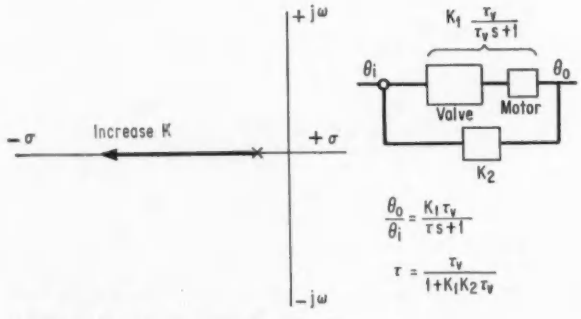
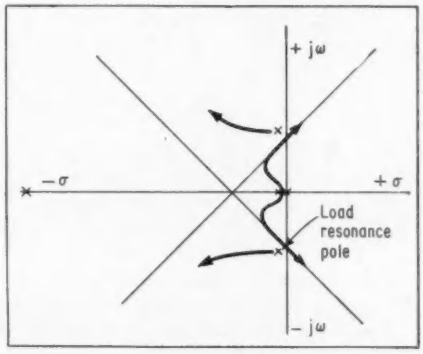


FIG. 8. Velocity-type switching servo is always critically damped, can have high response at high gain.

FIG. 9. Addition of load resonance to root locus plot can cause instability at very high gain, but switching servo can approach load resonance frequency more closely than proportional type.



the long flattened portion of curve 3 in Figure 6.

The root locus for the uncompensated servo is shown in Figure 7. As the gain is increased from K_1 to K_2 to K_3, etc., the root locus walks up a line parallel to the $j\omega$ axis. A practical check of the behavior of the switching servo is obtained from the fact that a high performance servo (20 to 40 cps passband) when uncompensated and excited with a square wave input will exhibit low damping, but it is still completely stable. The pilot shown in Figure 7 can be readily verified by starting at low values, like 100 psi, and gradually increasing system pressure (which has the effect of increasing system gain). For this test the actuator must be left unloaded to minimize higher order effects. This test proves that the valve may be accurately represented by a transfer function no more complicated than $K\tau_v\ (\tau_v s + 1)$.

In a velocity servo the integration of the actuator is not present. Figure 8 shows the root locus plot of a simple switching-type velocity servo. The servo is always critically damped, and increasing system gain moves the pole due to the valve time constant further and further into the left half plane along the $-\sigma$ axis. Such a servo can be made highly responsive by providing sufficient gain. Since the valve is a near perfect integrator, both the position and velocity servos exhibit essentially zero error characteristics.

Figure 9 shows the effect of a load resonance on the root locus plot of Figure 5. A pair of complex poles is introduced by the load resonance. Thus the acceleration switching servo can be operated with the upper end of its passband much nearer the load resonance than the proportional servovalve can be, thanks to the additional 6 db per octave "roll off" from the valve's integration.

SIZING THE SWITCHING VALVE

The acceleration switching gain K_a is the basic parameter by which the valve is sized. Once again,

$$K_a = V_s \times \frac{Q}{X_s}$$

where V_s = max spool velocity
Q = cu in. per sec flow for a spool displacement of X_s in.
X_s = spool displacement corresponding to Q

The valve flow gain Q/X_s may be referenced to any valve pressure, but it is customary to use the value corresponding to one-third of supply pressure to achieve optimum loaded working conditions.

Now to find the correct size valve for the following system specifications:

1. Force required: 2,000 lbs constant
2. Constant 0.75-in. amplitude output X_o required up to 10 cps
3. System pressure available: 3,000 psi

Taking 2/3 P_s across the load, the *actuator* must have an effective area of 1.0 sq in. minimum to meet the first requirement. If the system is excited with a sinusoidal forcing function at a frequency ω, the corresponding actuator motion will be:

$$X = X_o \sin \omega t$$

so $$\dot{X} = \omega X_o \cos \omega t$$
$$= 10 \times 2\pi \times 0.75 = 47 \text{ in. per sec (max)}$$

and $$\ddot{X} = -\omega^2 X_o \sin \omega t$$
$$= (10 \times 2\pi)^2 \times 0.75 = 2{,}960 \text{ in. per sec}^2 \text{ (max)}$$

now $$Q = A_A \dot{X}$$
$$Q = A_A \ddot{X}$$

Q = valve flow
A_A = actuator area
X = actuator displacement

The valve must therefore be able to deliver oil at 47.0 cu in. per sec with a drop across the valve of 1,000 psi. Further, the valve must have the capability of increasing flow at the rate of:

$$K_a = \dot{Q} = \omega^2 A_A X_o = 2{,}960 \text{ in}^3/\text{sec}^3.$$

Therefore, in order to satisfy the system requirements the flow capacity must be at least 47.0 cu in. per sec at 1,000 psi across the valve, and the valve must provide a switching gain of at least 2,960 cu in./sec^2 at 3,000-psi supply pressure.

THEORY OF VALVE CHARACTERISTICS

The valve transfer function $K_a\ \tau_v/(\tau_v\ s + 1)$ has been derived theoretically as follows:

Assume that the switching frequency is high compared to a sinusoidal input frequency ω. The valve must then meter oil to the actuator in accordance with the command and with a valve spool motion of amplitude X_s. The corresponding flow required to move the spool is:

$Q = X_s A_s$, where A_s = area of the spool

This flow must be supplied by the feed orifices and is controlled by the modulation index M. The flow rate dQ/dt is the total derivative:

$$\frac{dQ}{dt} = \frac{\partial Q}{\partial M}\bigg|_{\substack{P_{vs} \\ \text{const}}} \frac{dM}{dt} - \frac{\partial Q}{\partial P_{vs}}\bigg|_{\substack{M \\ \text{const}}} \frac{dP_{vs}}{dt}$$

where P_{vs} = pressure difference at ends of valve spoo
M = modulation index

$$M = \frac{\tau_1 - \tau_2}{\tau_1 + \tau_2}$$

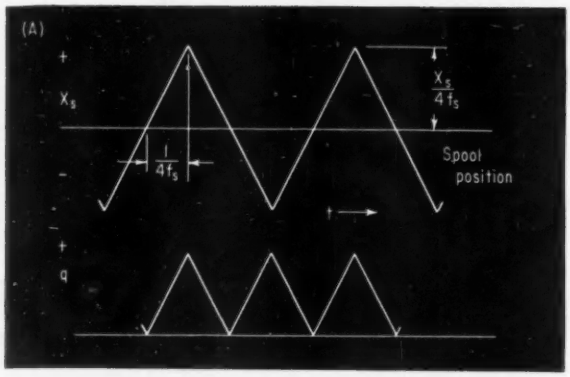
The pressure difference across the spool has three causes:

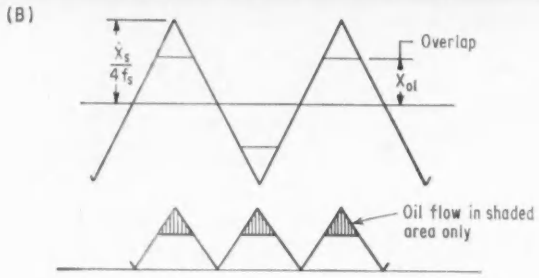
1. Friction between the spool and valve body
2. Spool inertia force
3. Flow reaction forces

Experience with the switching valve has established that items 1 and 2 are negligible at control frequencies and effective only at the switching frequency. Thus flow reaction forces alone produce the pressure difference P_{vs} across the valve spool at control frequencies. Blackburn and Lee of MIT showed some years ago that the flow reaction forces on a valve spool are given by:

$$F = 2Q\sqrt{\rho P_v}\cos\phi$$

where F = force on spool
Q = flow rate
ρ = specific gravity of fluid
P_v = pressure drop across valve
ϕ = flow entry angle (approximately 69 deg)
X_s = spool displacement

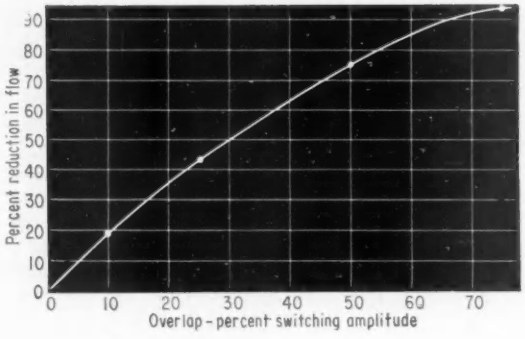




EFFECT OF VALVE OVERLAP

FIG. 10. Spool displacement and output oil flow for: A—zero overlap valve and B—positive overlap valve.

FIG. 11. Reduction in quiescent flow possible by overlapping spool-body orifices.



or it can be stated more simply

$$F = K\sqrt{P_v}$$

Then, $$P_{vs} = \frac{F}{A_s} = \frac{K\sqrt{P_v}}{A_s}$$

and

$$\frac{dQ}{dt} = \frac{\partial Q}{\partial M}\frac{dM}{dt} - \frac{K\sqrt{P_v}}{A_s}\frac{dX_s}{dt}$$

The flow rate through the first stage hydraulic amplifier is:

$$\frac{dQ}{dt} = A_s\dot{X}_s$$

so, $$A_s\dot{X}_s = \frac{\partial Q}{\partial M}\frac{dM}{dt} - \frac{K\sqrt{P_v}}{A_s}\frac{dX_s}{dt}$$

Rearranging and transforming:

$$\frac{\dot{X}_s(s)}{M(s)} = \frac{\frac{\partial Q}{\partial M}}{A_s} \times \frac{\frac{A_s^2}{K\sqrt{P_v}}}{\frac{A_s^2 s}{K\sqrt{P_v}} + 1} = \frac{K_1\tau_v}{\tau_v s + 1}$$

where K_1 = constant

$$\tau_v = \frac{A_s^2}{K\sqrt{P_v}}$$

As a matter of practical significance, the work of Blackburn and Lee considered the flow reaction forces for the case of two dimensional flow, whereas the flow in the metering section of a switching valve is more nearly three dimensional. The form $K' A_s^2/P_v$ has therefore been found to more nearly approximate the actual valve time constant.

Oil consumption

Oil consumption of the switching valve can be calculated as follows. Figure 10A shows a typical spool position trace and the resulting valve flow for zero overlap. Here,

q = instantaneous flow
K = constant (74.0 for MIL-O-5606)
C_d = discharge coefficient
W = slot width of valve metering area
T = period for one switching cycle
f_s = switching frequency

$$Q_{average} = \frac{1}{T}\int_0^T q\,dt$$

$$q = C_d\sqrt{\Delta P_v}\,A_v K$$

$$A_v = \dot{X}_s W t$$

so: $$Q_{avg} = 4f_s K \int_0^{\frac{1}{4f_s}} C_d\sqrt{\Delta P_v}\,\dot{X}_s W t\,dt$$

$$= \frac{K}{8f_s}\sqrt{\Delta P_v}\,C_d\dot{X}_s W \quad \text{(for zero overlap)}$$

If the valve is built with positive overlap, then the condition is as shown in Figure 10B

$$Q'_{avg} = Q_{avg}\left[\frac{\frac{\dot{X}_s}{4f_s} - X_{os}}{\frac{\dot{X}_s}{4f_s}}\right]^2$$

$$= Q_{avg}\left[\frac{\text{switching amplitude} - \text{overlap}}{\text{switching amplitude}}\right]^2$$

Figure 11 shows that the quiescent oil consumption of a switching valve can be made very low by carefully adjusting overlap and switching amplitude.

Investigating Thickness Control on Small Scale Rolling Mills

Thickness of rolled stock is maintained by controlling a mill's tension and screwdown forces. Initial investigations into suitable gage control schemes was done on an experimental, small scale rolling mill. Not only was a method found for simulating industrial size mills and their controllers, but the simulation actually eliminated the need for rolling any strip on the experimental mill while trying out the control techniques.

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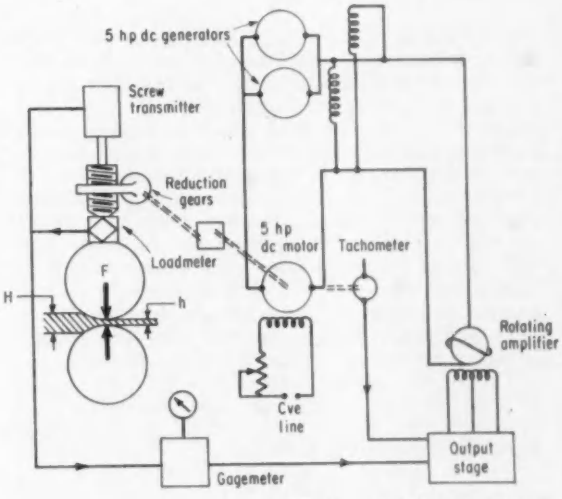
In the early stages of investigating control of rolling mills, the development of a closed-loop regulator proved too complex and the physics of metals rolling too little understood for experimental work to be attempted on an industrial size rolling mill. Moreover, the production time of an industrial mill is too valuable to be used for protracted experimental work needed in the first stages of development. Instead, control investigations were carried out in the Rolling Mills Laboratories of the British Iron and Steel Research Association. The experimental mill was a 10 x 10 in., two-high, cold mill with a maximum rolling speed of 300 fpm.

An analysis of mill performance showed off-gage material in cold rolling was due to changes in mill speed, in thickness of the incoming material, in strip hardness, and in tensions applied to the strip.

The first experiments in gage control used regulators which derived a signal from a continuous contacting thickness gage mounted on the mill's outgoing side. The error signal was applied to the mill's screwdown and tension control systems, both of which affected rolling load and hence the material's thickness. The experimental results were not entirely successful. The transport lag between a change in gage in the roll gap and its detection by the measuring equipment caused partial instability. Stabilizing would have involved a sampling servo with the period of sampling proportional to mill speed—never an entirely satisfactory solution. For this reason, a different approach to gage control was taken—that of measuring roll gap thickness by means of a loadmeter.

The mill-model equation

Controlling roll gap thickness without transport lag required development of the equation representing the mill as a measuring instrument and then verification that the experimental mill could be used as a true model for an industrial plant. Fundamental research discovered that an exact relationship existed between rolling load and the mill structure's elastic deformation.



Screwdown control of an experimental rolling mill.

The model relationship is simple enough. Let the gap between the mill rolls be S_0 and the strip material entering the gap be H, where $H > S_0$. The strip will then deform plastically under the load F applied by the rolls. The rolling load will, in turn, deform the rolls and the screws and also elongate the mill frame, the net result being an increase in roll gap. If the strip leaves the mill at a thickness h, the roll gap will have increased dimensionally from S_0 to h. From the laws of elasticity:

$$F = M(h - S_0) \quad (1)$$

where M is a factor of proportionality characteristic of the mill. Alternatively, if h' is the thickness setpoint and ϵ is the error, then:

$$h = h' + \epsilon \quad (2)$$

and

$$\epsilon = F/M + S_0 - h' \quad (3)$$

Since all terms on the right side of Equation 3 are known or measurable, the equation establishes the model law between the experimental rolling mill and larger industrial mills.

Mechanization and instrumentation of the model equation is shown in the figure. An accurate loadmeter employing strain gages measured the mill load F, synchros measured screw position, and a set of decade switches under control of the mill operator established the setpoint h'. Combining these electrical signals correctly gives the error signal, Equation 3, which varies the mill tension and screwdown control systems.

In practice, the error signal operates the screws only after the upper or lower limit of tension is reached. These limits are essential to prevent the strip running slack, or breaking under excessive tension. This faster action on the part of the tension loop occurs because the tension regulator does not integrate, but the screwdown control does have a stage of integration due to the screws themselves. As a result, the tension loop responds about five times faster than the screwdown loop.

Simulating the roll gap

With the equation of the rolling process well established, an automatic gage controller was built successfully for the experimental mill. The next task was to devise a method for the experimental mill to roll as a model of any industrial mill. However, loading of any particular mill varies over a wide range during production, so the next step in the investigation was to calculate the rolling load F under all conditions of loading. This led to the second important concept in model analysis, that of the roll gap transfer function. The mill operator has always known that when rolling thin, hard materials he needed to move the screw by a larger amount to change the strip gage than when rolling thick, soft stock. That is, the mill gain—the roll gap transfer function—changed with rolling conditions.

The roll gap transfer function α is the ratio: change in strip thickness divided by axial displacement of the mill screw. It can be determined by rearranging Equation 1 and differentiating:

$$h = S_0 + F/M \tag{4}$$

and

$$\alpha = \partial h/\partial S_0 = 1 + 1/M(\partial F/\partial S_0) \tag{5}$$

The value of the transfer function varies widely with mill and materials, but it is always less than unity. It may be shown that numerically α equals $M/(M + Q)$, where Q is the differential coefficient $(\partial F/\partial h)$.

It was not easy at first to simulate any value of the roll gap transfer function on the experimental unit. The modulus M of the experimental mill was 1,920 tons per in., whereas the large mills in steelworks have values between 9,000 and 13,000 tons per in. Moreover, the value of Q could not be varied easily on the experimental mill over the same range found in production. Similarity here is important. The overall gain of the tension and screwdown closed-loop regulators is directly proportional to the roll gap transfer function, having values from about 0.6 when rolling thick, soft steel down to 0.07 when rolling tinplate, thereby representing a nearly 10 to 1 change in loop gain. This change in gain will also occur in a reversing mill when rolling a single coil, making servo stability particularly difficult if operational simplicity is to be maintained.

Rearranged, Equation 5 becomes:

$$(\partial F/\partial S_0) = -M(1 - \alpha) \tag{5A}$$

With the rolls in contact under load (no strip in mill), $h = 0$. Then $\alpha = 0$ and $(\partial F/\partial S_0) = -M$.

When the control equipment is adjusted so that the loadmeter signal is reduced by a fraction $(1 - \alpha)$ of that required to give true gage readings, then the equipment will indicate a false gage:

$$h_1 = S_0 + F/M(1 - \alpha) \tag{6}$$

and

$$(\partial h_1/\partial S_0) = 1 + (1/M)(1 - \alpha)(\partial F/\partial S_0) \tag{7}$$

When the rolls of the mill are pressed together after this adjustment has been made to the loadmeter, the quantity $(\partial F/\partial S_0) = -M$, as before, since it is entirely a mill describing function which is not modified by circuitry. The value of the apparent roll gap transfer function then equals α whereas, of course, with the controller correctly adjusted it should equal zero. The screwdown controller will now therefore perform a control function with the rolls pressed together (no strip) identical to the performance when any mill with a correctly balanced controller is rolling strip with a transfer function of α.

A similar, but more complex arrangement may be devised for tension control, and with little modification to the control circuit a combined tension and screwdown controller may be simulated. The apparent roll gap provided a simple, cheap, and exact model technique for testing automatic gage control circuits and exploring the limitations of the regulators using very small laboratory equipment and the few technicians available in the laboratory.

Using the model mill equation and the technique of apparent roll gap transfer function to simulate any industrial mill operating over varying production conditions, the experimental mill offered a particular advantage in reducing control investigation costs: no expensive copper or steel coils were needed for the experimental mill nor was labor needed to transfer the coils on and off the mill.

The simulation technique also proved invaluable when the first controller was commissioned in industry. The screwdown control was an on-off regulator which was difficult to set up. With the limited experience then available to the technicians on gage control, they might have taken a long time and used a good deal of expensive material had conventional commissioning techniques been used.

Simulating friction effect

A parallel study into the causes of gage changes during acceleration and deceleration of the mill showed that the effect was due to the lubricant applied to the strip. The cause of this so-called speed effect was not obvious since no speed dependent variable entered into the calculation of the rolling load F. Since rolling friction is a property of the strip material, however, the discovery that the speed effect was a frictional phenomenon meant that model experiments could be carried out by changing the speed of the experimental mill without loss of generality when the results were applied to the larger, faster mills in industry.

Techniques of Dynamic Display

PART III: From TV Pickup to Matrix Cells

The final article in this series describes a wide variety of special techniques. Although these cannot be classified either as pure cathode ray tube techniques (Part I) or optical techniques (Part II) they are just as important. Some of the most promising developments in the display field are discussed here. They include:

- **TV pickups**
- **Character displays**
- **Drum storage systems**
- **Matrix cells**

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Lockheed Electronics Co.

Closed circuit television has transmitted such pictorial data as a missile launching, the rolls of a steel mill, and the entrance of a cement kiln to an operator who controls actuators based on what he sees. Closed circuit TV has also transmitted alphanumeric data from control panels and readout devices. TV's use in dynamic display is growing.

Several companies—among them Philco Corp., General Precision Laboratory Div. of General Precision, Inc., General Electric Co., Kin Tel Div. of Cohu Electronics, Inc., Blonder-Tongue Laboratories, Inc., DuMont Laboratories, Inc., and Dage Div. of Thompson Ramo Wooldridge, Inc.—make commercially available systems. Typical of these is the Dage Data-Vision. It can produce distant still pictures with a resolution of 180 to 400 lines vertically and corresponding resolution horizontally. Resolution is dependent on the rate of transmission and the equalization of the line. Three main pieces of equipment compose the system: the camera, a slow sweep device; a Data Control monitor that establishes the electrical operating characteristics of the system; and a Data Receiver for viewing, connected to the monitor via a radio link or telephone lines.

The television picture can be used directly, projected (see Part II, CtE, April '60), or combined with other techniques in such equipment as SPANRAD (superimposed panoramic radar display) built by Intercontinental Electronics Corp. In SPANRAD a composite display is obtained: information such as radar data is converted from a rho-theta scan to a television scan in a scan conversion tube. The output is mixed electronically with data obtained from a videcon picture. In an air traffic control application, for example, radar pips indicating location of aircraft are superimposed on an airline map on which a controller manually moves position markers identifying the flights. The composite display shows complete information on all aircraft in the area. Because of the persistence of the scan conversion tube, the target leaves a trail which supplies an air traffic controller with past history of the flight. The display is bright enough to permit daylight viewing.

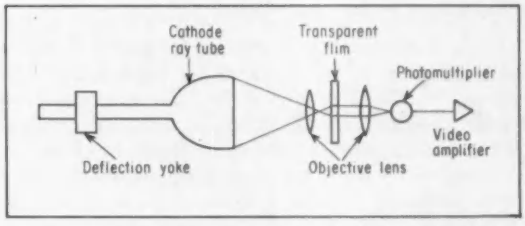


FIG. 1. Simplified drawing of the flying spot scanner.

Another application of TV is the flying spot scanner, a form of television camera that creates television signals from still images, Figure 1. A cathode ray tube as a source directs light through an objective lens to a transparent film. A photomultiplier converts the light to an electrical impulse which can be built up by a video amplifier. Vertical and horizontal magnetic deflection circuits move the CRT's electron beam and the "flying spot" of the short persistence cathode ray tube. Light output of the CRT is kept constant during scanning so the density of the slide or film affects light transmission. If an image to be reproduced is placed on the film, the image modulates the light beam.

Philco has applied this technique to display radar data in color. After photographing a radar plan position indicator on 35 mm film and rapidly processing the film, Philco scans the negative to convert the

polar coordinate radar signal to a Cartesian coordinate signal which can be applied to a shadow mask color tube. The amplitude of the video signal (modulated by passing through the film) determines the signal strength applied to each gun of the color tube in this manner:

Gray Scale	*Color Presentation*
0 percent (black)	Blue
25 percent	Cyan
50 percent	Green
75 percent	Yellow
100 percent	Red

At intermediate video signal levels, appropriate combinations of the primary colors produce intermediate hues. The scale can be reversed so that black (0 percent gray) appears red, and the remaining colors are reversed accordingly. If the full color range of the equipment is applied to a small segment of the gray scale, fine distinctions can be magnified in contrast many times.

Character Display Techniques

The generation of characters to identify data is not restricted to the cathode ray tube devices discussed in Part I of this series. In fact, character devices are not restricted to electronic techniques; others are electrical or electromechanical. Here are a number of character generating techniques that were designed to work with some kind of cathode ray tube (as opposed to techniques which are an integral part of the tube, discussed in Part I).

• **Skiatron character generator**—developed by Skiatron Electronics and Television Corp. to write any number of characters consecutively on the face of a standard or dark trace cathode ray tube. It uses the "Photoformer" technique in which the characters are individually drawn as in handwriting. Type of character generated depends on arrangement of transparent and opaque areas on mask (Figure 2).

When writing characters (such as A, E, F, H, K, and T) that cannot be written with a single stroke, the beam has to be lifted and moved or retraced over previously written areas. Time to write a character depends on the complexity of the character. The figure eight, for example, requires the most time since it is the most complex. Average time to write a character: 1/60 sec. Minimum time can be as little as a few hundred microsec.

If characters are interspersed with other information, such as radar video, the added data can be inserted when convenient, using parenthetical or deadtime insertion methods.

• **Wang character generator**—can supply all the signals necessary to display any character on a standard cathode ray tube. Developed by Wang Laboratories, Inc., it operates on the dot sequential principle, using a maximum of five horizontal and seven vertical dots per character. As the electron beam of a cathode ray tube scans across an area of the view-screen, characters are formed by properly intensifying the beam. Many different switching arrangements can be used to select the desired character. The Wang system can display 40 different characters at a rate of 10,000 characters per sec. Hundreds of additional characters are possible.

• **AMF technique**—produces target identification and other auxiliary information on a plan position indicator. In the system American Machine and Foundry Co. developed for the Signal Corps, information was presented three ways (Figure 3):

- three-digit numbers
- a dot code
- a straight line to indicate direction

Writing time is about 50 microsec for one entire symbol of the type seen in Figure 3. The information is presented during deadtime provided for this.

• **Dotitron**—positions closely adjacent luminous dots to compose alphanumeric characters or any arbitrary pattern of lines on the screen of a cathode ray tube. Character selection and display position order signals are parallel digital codes. The system, developed by the Link Div. of General Precision, Inc., is shown in Figure 4.

Here is how it works. The electron beam (blanked so there is no image on the face of the tube) is positioned at a key point called the suborigin of the character; each character has its special suborigin. To form a character, selected dot positions are located by relative deflection voltages introduced by resistor networks. The proper dot positions are determined when the resistor networks are designed. Additional characters can be incorporated into the equipment by adding the proper resistor networks for them. The beam is unblanked when it has been driven to the dot positions, creating the character.

A character generation technique that is quite different from those described above is the Union Indicator, developed by Union Switch and Signal Div. of Westinghouse Air Brake Co. to solve an air traffic administration problem. The indicator has an electromechanical positioning system to locate characters carried on a belt; it uses a six-bit code on six wires. A total of 72 characters are contained in the belt which is supported by two sprocket wheels, one with eight units in circumference, the other nine. For each combination of sprocket positions there is one distinct belt position, displaying one character. Mounted within each sprocket is a commutator, arranged to make contact selectively with a battery or with the detent magnet.

Each commutator has eight different codes (one code is repeated on the nine-unit wheel), so the number of different codes is 64 ($8 \times 9 - 8$), the maximum with a six-wire system. Eight different characters appear twice on the belt.

A Union Indicator can display one character at a time, $\frac{9}{32}$ x $\frac{13}{64}$ in. in size. Maximum time to change from one display to another is about 1.5 sec. By stacking indicators side by side and on top of each

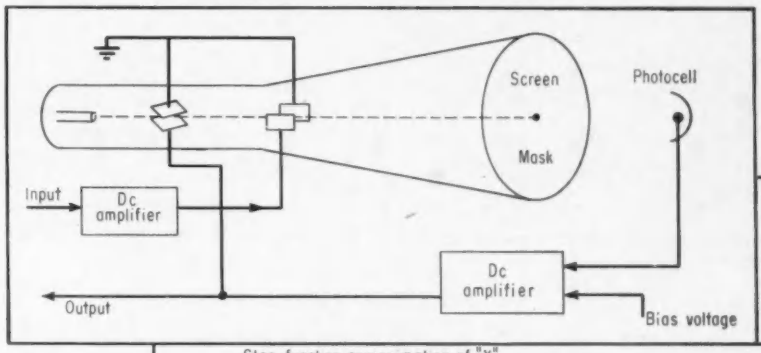
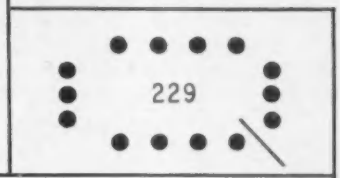


FIG. 2. Simplified drawing of the "Photoforming" technique.

FIG. 3. In the AMF character generation system, information is displayed in three ways: a three-digit number, a surrounding dot code, and a straight line to indicate target direction.



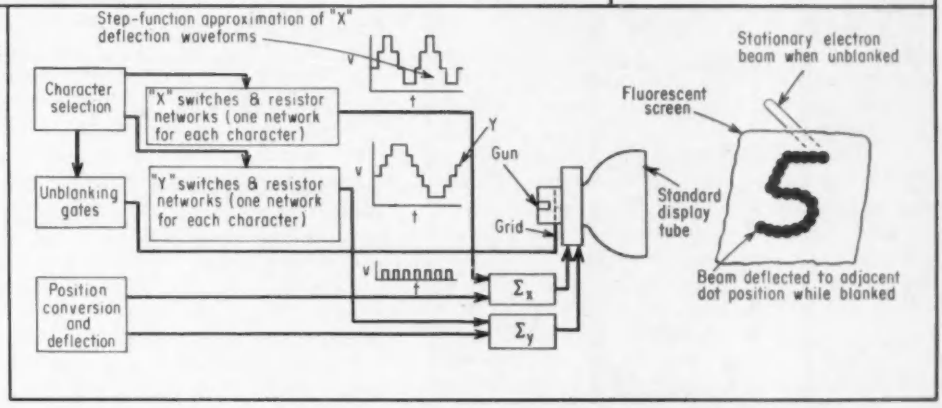

Step-function approximation of "X" deflection waveforms
Character selection
"X" switches & resistor networks (one network for each character)
Unblanking gates
"Y" switches & resistor networks (one network for each character)
Position conversion and deflection
Gun
Grid
Fluorescent screen
Standard display tube
Stationary electron beam when unblanked
Beam deflected to adjacent dot position while blanked

FIG. 4. Dotitron system.

other, a designer can build a complete tabular display which can be read horizontally or vertically. Such a system has considerable flexibility: data already displayed can be transmitted to associated equipment, the order in which rows of information appear can be changed, individual characters displayed can be changed, additional characters can be inserted, and an entire row of information can be erased at the push of buttons.

Another electromechanical character generating device is the digital indicator built by Teleregister Corp. In it, characters are contained on a rotatable drum which is operated by an armature and an electromagnetic coil. Standard drum contains the digits zero through nine and one blank space; drums, however, can be made with any arbitrary characters.

To rotate the drum one character, a pulsating current passes through the electromagnetic coil, pulling the armature so it deflects a spring. When the current is shut off, the spring drives the armature which causes a pawl to strike the drum and rotate it.

Teleregister makes two models: Type K with a $\frac{3}{16}$-in. character and the Type 68 with a $\frac{1}{2}$-in. character. The Type 68 has an inherent storage feature, and the information can be read out in code for transmission to other locations.

To build a tabular display, groups of these indicators are assembled in housings, and the housings can be mounted in rows and columns. The display from one indicator can be transferred or copied by another without disturbing the display of the original.

A silent, relatively fast electromagnetic display is built by Sigma Instruments. Up to 11 characters are arranged on a display drum which is gear-belt driven by a magnetic, brushless motor called the Cyclonome Stepping Motor. Because of the design of the motor and the absence of drive gears, the device operates noiselessly.

On the number display drum are brushes which engage a printed circuit wafer switch. When a code signal is sent to the display, the motor advances the drum one position for each full ac cycle (or one for each dc pulse), until the desired position is reached. An external halting relay is energized through the drum wafer switch to stop the motor.

Two sizes are available: $\frac{3}{8}$ in. x $\frac{9}{32}$ in. and 1 in. x $\frac{5}{32}$ in. The drum rotates at a speed proportional to input frequency. At 20 cps, maximum time to move from the two most distant characters is $\frac{1}{2}$ sec. A life of 20 million indications is claimed.

Other individual character generating devices are the Industrial Electronic Engineers digital indicator, the Burroughs Nixie, and the National Union Electric Corp. Inditron. IEE's device consists of 12 individually actuated lamps, each with a condensing lens on which a character has been reproduced. When the proper lamp is lit, an optical system projects the character on its associated lens. Tabular

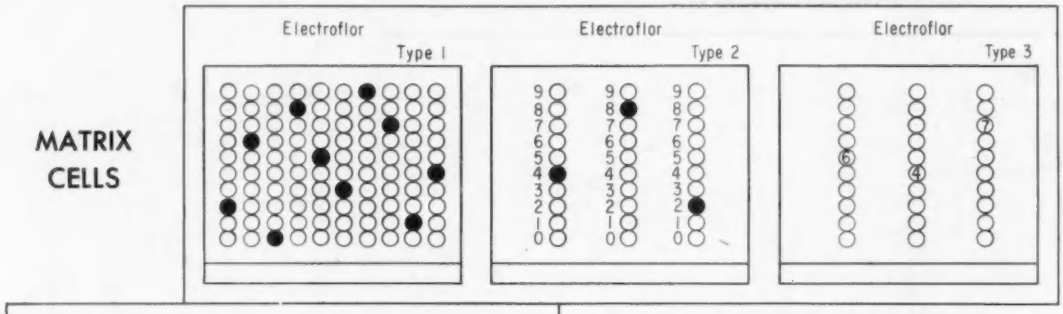


FIG. 6. Three types of Electroflor displays.
Type 1: unmarked indicator dots in rows; dots are white until activated when they become blue.
Type 2: vertical rows of indicator dots with numbers printed at left of dots.
Type 3: vertical rows of dots with numbers printed on the dots, numbers show up as a strong blue against a white background when dots are activated.

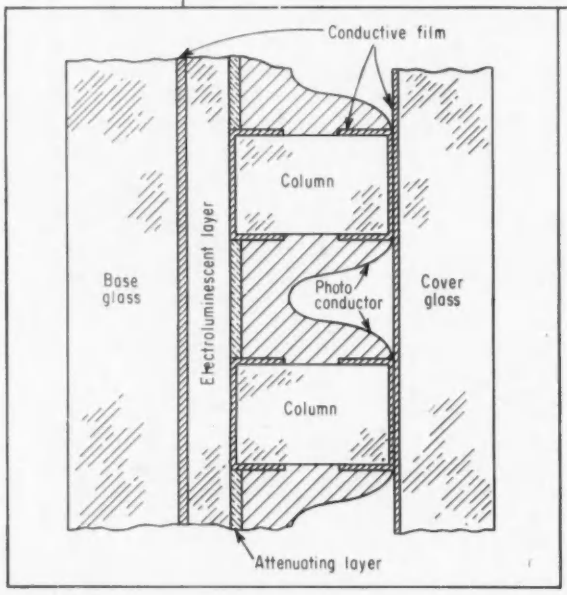


FIG. 5.
Electroluminescent storage panel.

displays can be stacked horizontally and vertically. Since the character is reproduced on the lens photographically, short messages—such as stop, start, danger, etc.—can also be displayed. The IEE device can be built in any size. The Federal Aviation Agency even considered the use of giant IEE indicators at the end of runways to flash takeoff instructions to pilots, thus easing the load on already overtaxed radio communications.

The Nixie is a gas-filled cold-cathode tube with 10 stacked character-shaped filaments (zero through nine) sharing a common anode. When one of the filaments is excited, a glowing character can be seen through the transparent glass view dome. The Inditron is similar to the Nixie.

Drum Storage Systems

Some display systems are using techniques developed and perfected for computer applications. Information is stored in magnetic drums and is then synthesized into displays. The result is a processed display. Typical of such systems is the one RCA has designed to convert binary digital inputs to a color plan position indicator display.

Generated by track-while-scan channels, the input consists of up to 10 35-bit words plus timing and target pulses. In each word 10 bits represent *x*-position; 10, y-position; 6, x-velocity; 6, y-velocity; and 3, color. The words are stored on the drum approximately 210 microsec apart so that the targets appear with a repetition rate of 46 cps. A decoder converts the digital inputs into the analog outputs which are presented on a tricolor shadow mask tube. The system can produce six colors and white; the display is bright enough to be viewed in a normally lighted room.

Remington Rand Div. of Sperry Rand Corp. has also built a drum system which it calls TACS (its transistorized counterpart has been named BADGE). TAC's magnetic drum can store and decode radar and ancillary information on 100 targets for display on a cathode ray tube.

Target information is stored as four words each of 10 binary digits, plus a leading word which determines where the next four target words will be recorded. In an aircraft tracking application the first word contains identity information, the third, altitude data—both are termed ancillary information. The second word is the x-coordinate, the fourth, the y-coordinate. Ancillary words, converted to a distributed octal array, can be brought out of storage by a light gun or by preset buttons on counters. The information appears as lighted words.

The Air Force's famous air warning system, SAGE, (Semi-Automatic Ground Environment) also uses magnetic drum storage and readout—actually two drums. The computer feeds positional information on each target to the Radar Data Drum from where it is finally presented on a Charactron as a series of nine symbols which indicate the direction of travel. Each of the symbols is stored in a separate "field" of the drum (there are nine fields) so that each field represents the position of all the targets at a particular instant of past time. Information on the oldest field is continually being removed and replaced with new information; symbols are added

at the front of each track and dropped off the rear. Complete readout of the Radar Data Drum to the Charactron tube takes 1 sec.

On the second drum—called the Track Data Drum—are stored messages containing different kinds of information like video mapping symbols and geographical reference signals. Information is read out from this drum to the Charactron tube; total readout of the drum takes 1.5 sec. A single message can be read out in 1 millisec.

Matrix-Cell Techniques

One of the newest display techniques involves assembling in a regular pattern (matrix) a discrete number of individually excitable light producing or absorbing elements (cells). Probably the biggest advantages of this technique are 1) it lends itself to thin displays which do not require vacuum, and 2) devices are not fundamentally limited in size the way the size of a vacuum tube is limited. The cells of the matrix display may be solid, liquid, or gaseous state material—in an appropriate binder or contained in an appropriate small cavity. Most of the equipments described below work with electroluminescent material—either alone or in conjunction with photoconductive materials.

Three types of electroluminescent display have been proposed by Sylvania Electric Products Div. of General Telephone & Electronics Corp. The simplest is the Panelescent lamp, which is a layer of electroluminescent material sandwiched between thin transparent layers of a conducting material such as tin oxide. A voltage across the two conducting layers causes the inside material to luminesce.

In the second type the electroluminescent material is sandwiched between two arrays of parallel wires oriented at right angles to each other. This divides the electroluminescent layer into a large number of cells, any one of which can be excited by the application of a voltage to corresponding wires.

The third type has been called the Light-in, Light-out storage panel; Lincoln Laboratory of MIT has also studied such a technique. This device (Figure 5) combines photoconduction with electroluminescence. The display is made up of many individual cells which, when triggered with a small pencil light, luminesce. Once triggered, the cells remain lit indefinitely. Triggering takes about 1 millisec.

Lincoln Laboratory is also studying a device which combines an electroluminescent matrix with the light storage technique. Voltage applied to the proper wires of the proper matrix cell triggers the electroluminescent material of that cell.

Westinghouse Electric Corp. offers commercially an electroluminescent digital readout which displays all the letters of the alphabet, all the numerals, and a number of symbols. Each character is 2¾ in. high. Each of the lamps, called Alpha lamps, is divided into 14 segments of electroluminescent material. Characters—alphabetic, numeric, or symbolic—are formed by lighting the proper segments.

At least one company, Shannon Luminous Materials Co., has developed a matrix cell display using liquids which are called Electroflors. There are two types: fluorescent and nonfluorescent. The liquids fill small cells, each of which is equipped with two electrodes. If a cell containing a fluorescent Electroflor is electrically charged, the liquid fluoresces when an ultraviolet light is applied. If a cell containing a nonfluorescent Electroflor is electrically charged, the liquid changes from clear to colored. Because the nonfluorescent-type cell depends on the subtractive light principle, it has no light output of its own; it must be illuminated by external light. Figure 6 shows typical arrangements.

Contrasting with electroluminescent materials which are generally operated on ac voltages, the Electroflor cells are direct current devices. The liquid cells can be built to have a memory that will last up to five minutes. They can be read out nondestructively. And displays can be built with as many as 50 cells per in.

A gas-filled matrix device has been developed by General Electric Co. to read out analog information in digital form. Basically it is a flat vacuum tube composed of a matrix of gas-filled cells and wires.

BACKGROUND READING

For those interested in learning more about display, here is a list of references selected by the author. These cover techniques and hardware described in all three articles.

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INVESTIGATION OF TECHNIQUES FOR DISPLAYING INFORMATION IN AN AIR TRAFFIC CONTROL CENTER, Stavid Engineering, Inc., May 1958, AFCRC-TR-58-113, ASTIA Document No. AD 146829.

Eidophor

HIGH INTENSITY COLOR TELEVISION FOR VERY LARGE SCREEN PROJECTION, C. L. Ellis, AIEE Conference Paper 55-779, October 1955.

Scan Conversion Tubes

THE INTEC TMA-403X VIDEO TRANSFORMATION TUBE, Intercontinental Electronic Corp., Mineola, N. Y. (brochure).

6896/1855 GRAPHECHON SIGNAL CONVERTER STORAGE TUBE, RCA Tentative Data Bulletin, January 1958.

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A COMBINED CAMERA, RAPID PROCESSOR AND PROJECTOR, W. A. Pfaff and G. Lysle, "Photographic Engineering", Volume 6, No. 2, 1955.

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6866 DISPLAY STORAGE TUBE, RCA Tentative Data Bulletin.

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IATRON BROCHURES, Farnsworth Electronics Co.

Color Cathode Ray Tubes

TV TUBE BRINGS COLOR TO RADAR, J. Holahan, "Aviation Age" ("Space/Aeronautics"), September 1955.

NEW FLAT COLOR CRT USES FOLDED-BEAM, "Electronic Industries", January 1957, p. 80.

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Charactron

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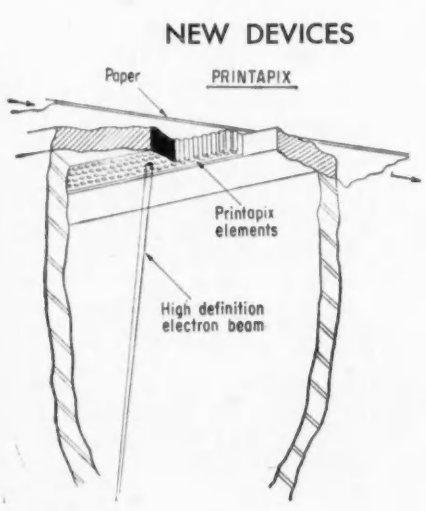
CHARACTRON DISPLAY TUBE, Stromberg-Carlson, San Diego, Calif. (data sheets).

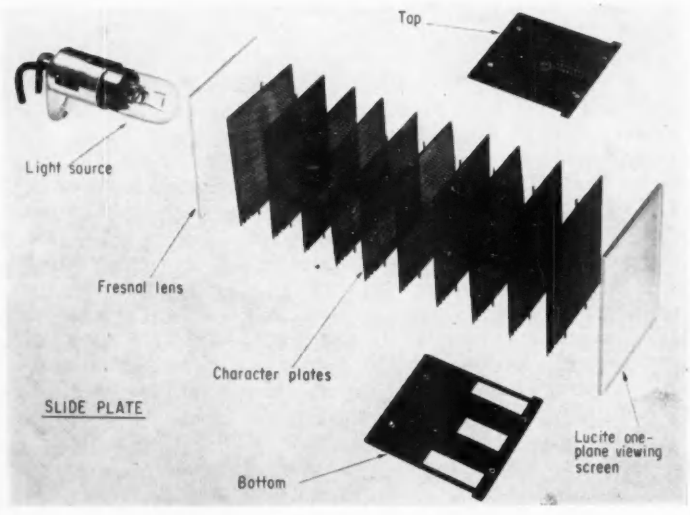
Flat Cathode Ray Tubes

NEW FLAT COLOR CRT USES FOLDED-BEAM, "Electronic Industries and Tele-Tech", January 1957, p. 80.

A THIN CATHODE-RAY TUBE, W. R. Aiken, IRE "Proceedings", Volume 45, No. 12, December 1957, p. 1599.

NEW DEVICES





And More . . . The bulk of the material for this series was accumulated in a project which the author completed in 1958 for the U. S. Air Force. Some of the material has been updated before its publication in CtE, but the field of dynamic display is moving so fast that new developments have come along since the series started. Here is a brief description of some of these recent innovations:

Pintapix—developed by Litton Industries—electronically prints at high speed on nonsensitized dielectric material. Suggested applications: facsimile, oscillography, address labeling, high speed computer readout, projecting transparency generation, and multiple copy reproduction.

Slide Plate—developed by Industrial Electronic Engineers—accepts binary coded decimal input and displays alphanumeric characters without a complex conversion unit. Models are available to display numbers (zero through nine), 10 characters, 40 characters, and 64 characters. The device consists of a number of thin character plates lit from behind through a Fresnel lens. The binary coded decimal input causes vertical movement of the one character plate to be displayed. As a result, that character can be seen on a Lucite viewing screen. Slide Plate works on such a low signal power input that it can be connected directly to transistor or vacuum tube flip-flops without intermediate buffers or amplifiers.

What's Available in Europe For Electronic Process Control

Electronic controllers are not new to European process firms. In 1950 Britain pioneered the world's first electronically controlled refinery in South Wales.

Instrument manufacturers in Europe now offer 13 electronic control systems. As might be expected, these systems differ considerably from those made in the United State (see reference). But more important are the significant differences among the Europan systems themselves. No clear technical pattern is being followed. For example, while all US electronic control systems employ "live" zero, most—but not all—European makers prefer "dead" zero. All American controllers deliver a dc current signal; European controllers produce a variety of outputs: current, voltage, and even pneumatic signals.

The large number of available electronic control systems from Europe and their diversity complicate their selection. This first of three articles takes a broad look at equipment designs and trends and gives a detailed description of two systems. The essential characteristics of all 13 electronic systems are summarized in a table. Descriptions of the remaining 11 systems will follow in Parts II and III.

DEREK BARLOW, Control Engineering
ERNEST D. MAY, London, England

Early European controllers often used electromechanical or electropneumatic combinations within the controller itself. For instance, the Allgemeine Elektricitats Gesellschaft (AEG) swing coil controller, development of which started in 1952, uses pneumatic elements to generate integral and derivative terms. Later designs used resistance-capacitance networks as the time function generators, and these *RC* networks are used in the majority of the most recent controllers appearing in Europe. Furthermore, two firms have improved on the straightforward *RC* technique to permit small capacitances to be adequate for large reset times. Schoppe & Faeser uses a Miller integrator; Evershed & Vignoles uses a dc "nonleaky" circuit.

Controller inputs have a variety of configurations including resistance networks, moving coil inductive pickoffs, and galvanometers with pointer mounted vanes generating the deviation signal photoelectrically, inductively, or capacitively in rf oscillator circuits. These configurations may be classed either as electromechanical or all-electronic error sensors.

Some early models of European controllers embody features based on obsolescent design standards. Methods like tubes operating in parallel and built-in anode current indicators reflect users' earlier lack of confidence in the life and reliability of thermionic tubes. In Europe at present, only two systems are fully transistorized—the Transitrol system developed by the French firm Controle Bailey and the Arca-Broida electropneumatic controller.

A characteristic feature of European process controllers is their multiunit construction. Such early designs as the UMC system of Hartmann & Braun used separate units for each of the proportional, integral, and derivative terms. Even the new Bailey transistorized controller requires a separate derivative term generator. But the construction trend is swinging fast to standard size — 144 x 144 mm — controllers with all three terms generated in a single unit. Maintenance is eased in these latest models by providing built-in test points and easily withdrawn

printed circuit cards. Typical of the latest European equipments with single unit construction are those of Joens, Electrofact, and Evershed & Vignoles.

While controller design tends toward the current American practice, one outstanding facet of the European field is the lack of a combined recorder-controller. Small markets are blamed for this. Engineers at European control makers feel that—with a scarcity of development money—separating recorders and controllers into individual units allows them to concentrate the available money on that unit they want to improve. Modular construction of recorders and controllers is the compromise solution adopted by European makers to give conformity in size and mounting details, although several companies are just now starting to develop combined units.

Earlier designs had rugged construction with strong weatherproof, cast cases, while newer models embody lighter housings designed for mounting on indoor instrument consoles and panels.

Most control firms in Europe market a comprehensive range of transmitters or provide means of adapting their controller input circuits to accommodate other makers' transmitters. The transmitters employ either force balance or electrical null. Only a few transmitters provide local indication. The number of wires required between transmitter and controller varies from two to five. All transmitters use two wires to carry the signal to the controller. Most force balance transmitters derive their energizing supply from a power line source in the field, eliminating power leads from control room to transmitter site.

Explosion-proof construction and intrinsically safe transmitting systems are not provided by all firms and, for the most part, transmitters are supplied that are suitable for outdoor mounting.

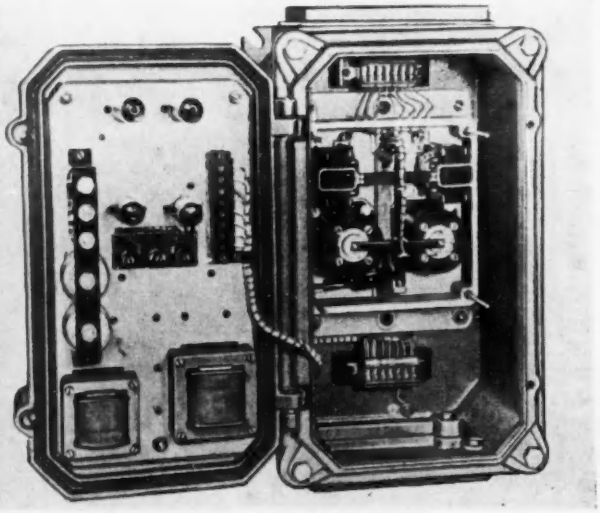


FIG. 1. Askania temperature transmitter.

Most European electronic process control systems employ electropneumatic converters and conventional pneumatic control valves. Only two firms, Askania and Evershed & Vignoles, emphasize both electrohydraulic and electropneumatic actuators. Third preference may be given to electric-motor actuators linked to the controller output by an additional power amplification stage.

New concepts in control

Two recent electronic process control systems—the Siemens Teleperm and the Arca-Broida controllers—show a complete breakaway from traditional controller design principles. The Siemens Teleperm uses magnetic amplifier on-off control, with pulse duration and frequency modulation feedback to yield proportional and reset actions which are nonlinear with respect to the deviation signal magnitude. The advantages claimed for this approach over conventional linear methods are faster settling time and reduced susceptibility to system noise.

Constructional simplicity and low cost highlight the Arca-Broida electropneumatic controller. In this system an electrically generated proportional signal and pneumatic servo generated reset and rate actions are combined with transistor actuated solenoids to provide a pneumatic output signal.

Askania-Werke AG, Germany

Electronic control system development by Askania commenced in 1940. The Askania system includes a comprehensive range of transducers, controllers, and all-electric or electrohydraulic actuators. A typical system contains these units: transmitter, mixer and desired value generator, control amplifier, generator for reset and rate terms, and actuator. System accuracy claimed is 0.5 percent FS.

Force balance transmitters provide pressure, level, and flow measurements. These variables manifest themselves as a displacement of a beam balance to which is attached an inductive pickoff. The signal from the pickoff is converted to 0- to 120-ma dc current which is applied through a magnet and pot coil assembly to balance the beam. The value of this balance restoring current corresponds to the magnitude of the measured variable and serves as the two-wire input signal to the series connected indicators, recorders, and controllers.

Current compensation is used in Askania's temperature transmitter, Figure 1. The emf from a thermocouple is applied to a resistor connected in series with a beam-mounted coil situated in the field of a permanent magnet. An inductive pickoff detects beam deflection, generating—via a two-tube amplifier—a 0- to 120-ma dc current. This restoring signal bucks the input, reduces net coil current to zero.

In the mixer unit a reactance bridge develops a 0- to 10-vac deviation signal proportional to the difference between 0- to 120-ma dc current from the transmitter and a setpoint signal derived from a

CHARACTERISTICS OF EUROPEAN ELECTRONIC PROCESS CONTROL SYSTEMS

	TRANSMITTER			CONTROLLER					
	Local indicator	No. of wires (see note)	Measured value signal	Output signal	Amplification	Proportional band, percent	Reset time, minutes	Rate time, minutes	No. of units for 3-term control
ASKANIA-WERKE Germany, 1940	No	4	0–120 ma dc	0–150 vac	2 tubes and magamp	0–100	0–10 0–60	0–1.6	3 or more
EVERSHED & VIGNOLES Great Britain, 1947	Yes	5 X	0–15 ma dc	0–15 ma dc	3 tubes	5–325	0.05–30	0–3	1
SCHOPPE & FAESER Germany, 1959	Yes	4	0–12 vac	0–3 ma dc	6–9 tubes	2–∞ switched	0–2	Under development	3
ALLGEMEINE ELEKTRICITATS GESELLSCHAFT Germany, 1952	No	2 or 3 X	———	3–15 psi	2 tubes	1–20 5–100	0.1–60	0.1–60	1
HARTMANN & BRAUN Germany, 1956	No	4	0–20 ma dc	−10 to +10 ma dc	2 tubes and magamp	1.5–100 1.5–300	0.05–20	0.05–20	Up to 5
SIEMENS & HALSKE Germany, 1957	No	4	Temp: 0–10 ma dc P and Δ P: 5–50 ma dc	Relay contacts	Magamp and relays	0–300 nonlinear	0–0.6 0–8	———	3
W. H. JOENS Germany, 1957	No	4	0–50 mv dc 0–5 mv with preamplifier	0–15 ma dc	2 tubes	0–100 0–1,000	0.25–25 0.25–∞	0–5	1
ELECTROFACT Netherlands, 1956	No	2 or 3 X	0–25 vdc	0–110 vac	6 tubes	2–500	2–200 sec 20–2,000 sec	0–2	1
CONTROLE BAILEY France, 1958	Yes	4	1–11 vdc	10–110 ma dc 2–22 ma dc	8 transistors	3–200	0–25	0–18	3 or more
CONTROLE et REGULATION Magdyne system France, 1959	No	4	0–10 ma dc	0–10 ma dc	Magamp	2–200	0.01–10	0.2–10	2
CONTROLE et REGULATION Transop system France, 1959	No	4 X	0–500 mv ac	1–5 ma dc	1 tube	2–200	0.01–30	0.01–30	2
ECKHARDT Germany, 1959	Yes	4	0–10 ma dc	0–10 ma dc	3 tubes and magamp	1–240	0.2–40	0.1–10	1
ARCA-REGULATEURS France, 1959	No	3 minimum	0–6 vac	3–15 psi	1 tube	0–100	0–30	0–1	1

Note: X shows transmitter excitation derived from controller.

voltage divider energized from a stabilized dc supply. Additional inputs on the mixer, four dc and two ac, allow ratio setting, manual reset, and cascade operation. For flow measurements derived from sensing of differential pressure, the necessary square rooting is usually accomplished in the transmitter.

Deviation signal amplification is carried out in a tube-magnetic amplifier combination. Two tubes in parallel offer increased reliability. Magamp output provides a 0- to 150-vac signal developing 40 watts maximum for actuator operation. Proportional band control between 0 and 100 percent is by potentiometer setting of the feedback voltage generated by an inductive transmitter mounted on the actuator. The alternative method for proportional band control—amplifier gain variation—is used only when advantageous to the system's dynamic operation.

Reset and rate terms are added to the control system by including individual timing units at the controller input or in the feedback loop. Electrical *RC* networks provide a 0- to 10-min reset time and a 0- to 16-min rate time. An integrating drag cup motor with adjustable eddy current braking extends reset times up to 60 min.

Drag cup motor actuators are used on the Askania system with either mechanical or hydraulic drives giving torque outputs up to 400 kg-m. Gearing attachments provide an 80-deg mechanical rotation for valve operation. The gearing can be used for manual positioning in the event of supply failure. Explosion-proof housings are available for the all-electric and electrohydraulic actuators.

Evershed & Vignoles Ltd., Great Britain

Evershed & Vignoles is one of the companies that fostered the use of miniature, 5½ x 5½ in., panel mounted electronic controllers, Figure 2. Development started in 1947, with the first major installation at the Llandarcy oil refinery in 1950. Later major installations were in the food, steel, nuclear, chemical, and power industries.

The Evershed system uses 0 to 15 ma dc for both measured (input) and control (output) signals. A unique feature is the complete noninteraction of all three control modes, achieved by a specially developed R-W (Redding and Warder) coupler. The controller employs three tubes plus a neon-tube stabilized power supply.

Figure 2 also shows the Evershed & Vignoles electronic controller with its side mounted test facilities. Auto-manual switching, cascading, and manual resetting facilities are included. Controller front indicators show measured and desired values and controller output.

Five-wire force-balance transmitters, with local indication, generate the measured value signals for pressure, differential pressure, flow, specific gravity, and level. Power for these is derived from the controller. For temperature measurements the transmitter is replaced by a dc bridge with a built-in dc amplifier and stabilized supply. The amplifier raises the signal level to the 0- to 15-ma dc controller input. System accuracy claimed is 1 percent FS for most transmitters, unaffected by plus or minus 10 percent line voltage variation. The transmitter's small signal current permits intrinsically safe installations.

In the controller the unique R-W tube transformer coupling circuit generates an ac voltage proportional to, but electrically isolated from, the measured value input, Figure 3. The effect of tube characteristic variations is eliminated by operating the tube as a variable resistance. After rectification the output voltage is connected in series opposition with the set-point signal to yield the error voltage. Adjusting the resistor network fixes the proportional range, and varying the cathode resistor of the second tube establishes the proportional band between 5 and 325 percent. A bidirectional output is obtained

FIG. 2. Evershed & Vignoles electronic controller with plug-in printed circuit cards and built in test facilities.

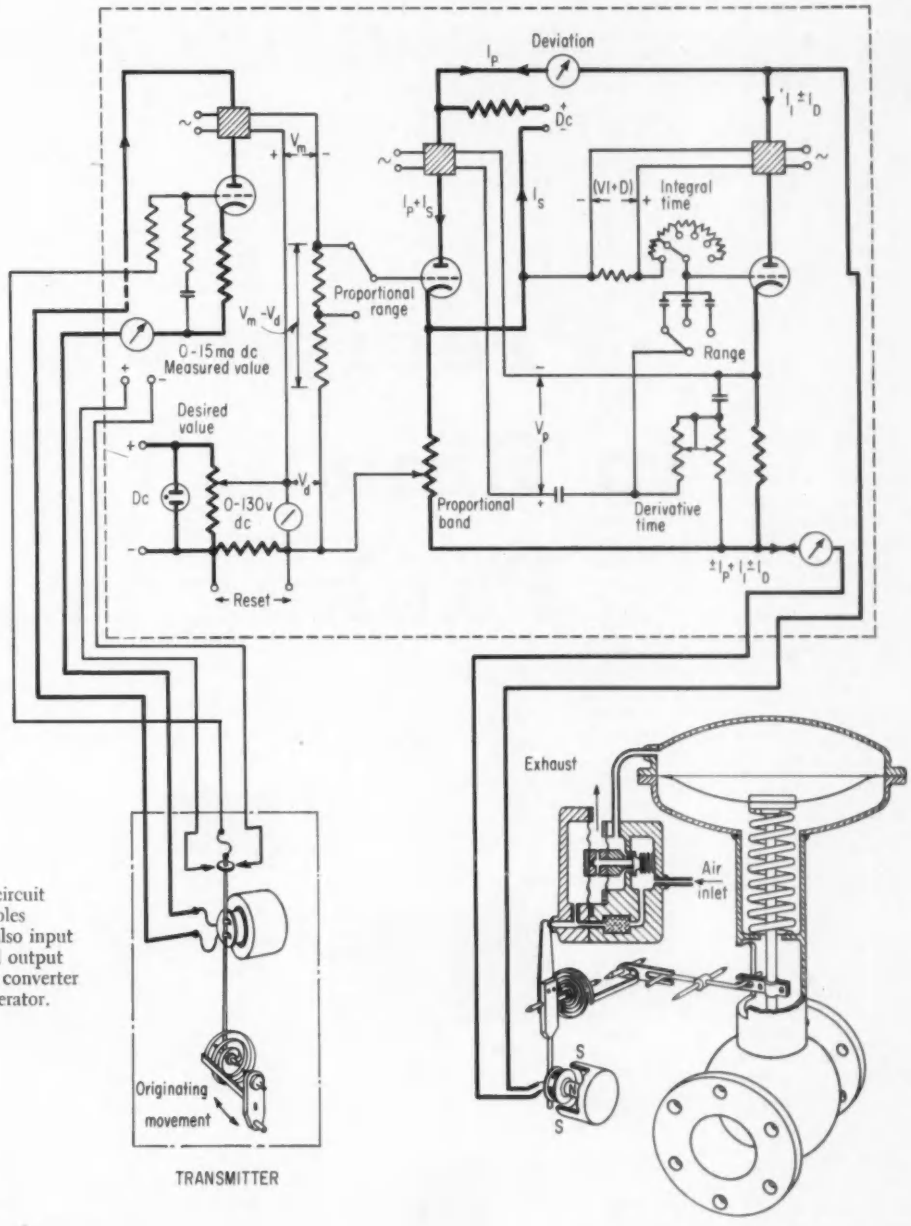


FIG. 3. Simplified circuit of Evershed & Vignoles controller, showing also input from transmitter and output to electropneumatic converter and then to valve operator.

by applying through the tube circuit a current equal and opposite to that flowing in the tube at zero deviation.

The voltage across the proportional-tube cathode resistor feeds the reset action *RC* network. Switch selection of three capacitance values controls the reset action coarse range, while the fine adjustment is from a variable resistance. Feedback from an R-W coupler in the anode circuit of the reset-rate tube applied to the integrating capacitance extends reset times to values well above the time constants of the resistances and capacitances actually used. The available reset times range from 3 sec to 30 min.

Rate action, from a second R-W coupler in the proportional amplifier, is generated by the output voltage being fed to the *RC* derivative network. The resulting rate voltage varies the current in the integral-derivative tube, the 0- to 3-min rate output being added to the proportional signal.

Actuators for the system include self-contained electropneumatic converters, positioners and electrohydraulic actuators with outputs to 40,000 lb-in.

REFERENCE

ELECTRONIC PROCESS CONTROL SYSTEMS, Harry R. Karp, "Control Engineering", November 1958, pp. 81-96.

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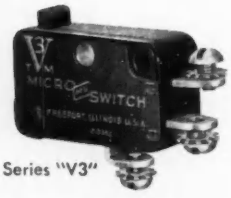

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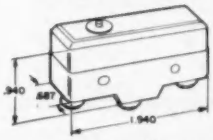

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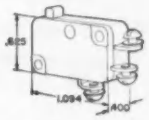

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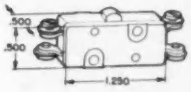

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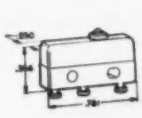

"SM" Subminiature Switches bring MICRO SWITCH precision to applications where space and weight limitations are critical. Many different "SM" types are available to meet varying requirements for high-temperature applications and long operating life. Special gold or bifurcated contacts are also available.

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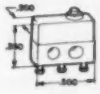

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Eliminating Diode Redundancy in Encoding and Decoding Matrices

THE GIST: Diode matrices should use a minimum number of diodes. It's cheaper this way, and diodes that are not there cannot fail. Diode saving in the case of encoding and decoding matrices is based on a simple set of rules applied repetitively. Once learned, the technoque yields near optimum design in less than an hour.

ARTHUR FREILICH
Burroughs Research Center

An encoding matrix has N input functions and M outputs, with the provision that only one input occurs at a time although 1 to M outputs may result from the single input. Figure 1 is an encoding matrix for converting decimal code information to binary representation. The matrix as shown does not use the minimum number of diodes. The number can easily be reduced from 15 to 11 diodes.

A decoding matrix is essentially the reverse of the encoding matrix, with multiple inputs and a single output. However, for N independent input functions it is necessary to have $2N$ inputs, since the complement of each input function is also required. There are always, therefore, N active inputs and one output. The inputs are four pairs of complements. One lead in each pair is connected to ground at any one time, so that a total of four leads is so connected. This article concentrates on the encoding matrix.

The Repetitive Evaluation Method

The repetitive evaluation method consists of systematically determining the increase or decrease in the number of diodes which will result from combining various logical functions in the matrix. Choices of combinations are made to yield the maximum diode saving, and the procedure is repeated for the revised matrix until no further saving is

BEFORE

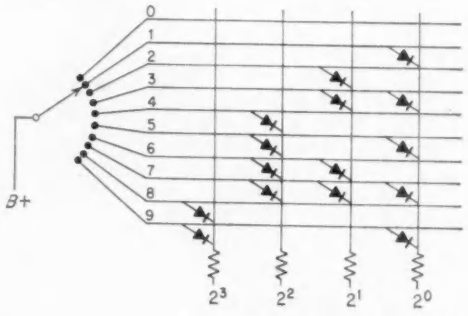


FIG. 1. Diode matrix for encoding decimal numbers to binary code.

and AFTER

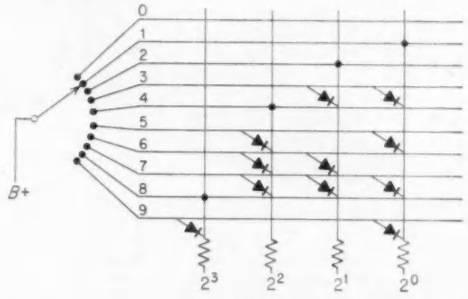


FIG. 2. Using Rule A saves four diodes compared with Figure 1.

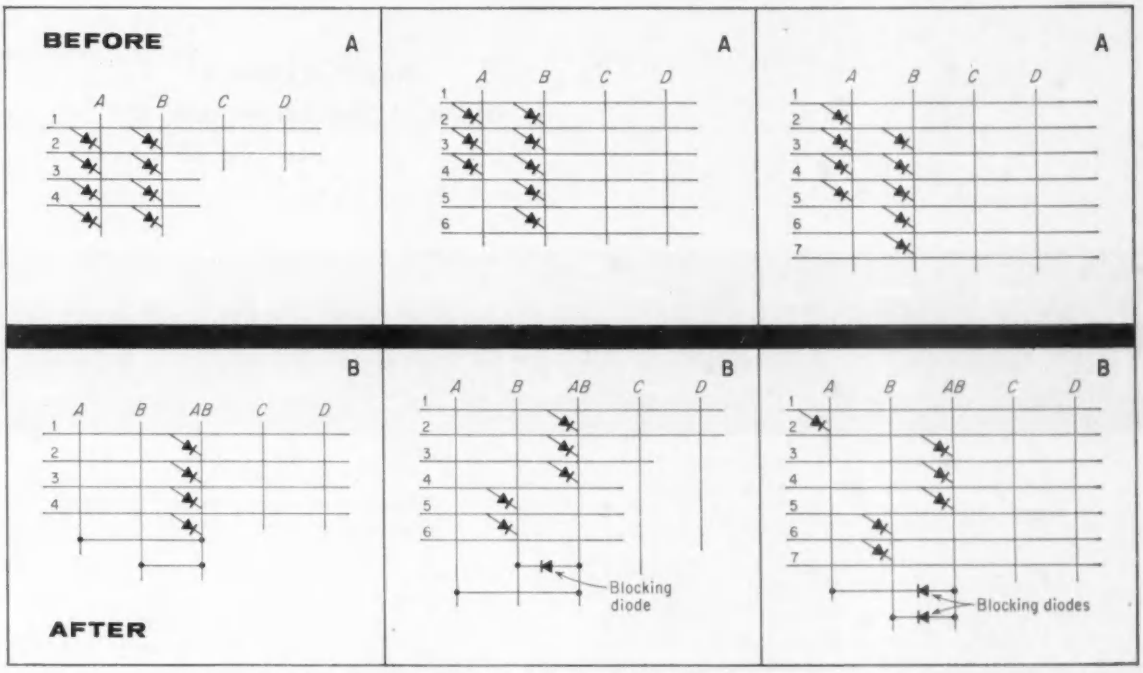


FIG. 3. Rule B, Case 0.

FIG. 4. Rule B, Case 1.

FIG. 5. Rule B, Case 2.

possible. The repetitive method is based on the following three relatively simple rules.

Rule A for saving diodes

Where an input is connected to only a single output, a direct wire connection can usually be used in place of a diode. For example, the diodes shown on input lines 1, 2, 4, and 8 in Figure 1 can be replaced by direct wire connections as shown by the dots in Figure 2. The new matrix calls for 11 diodes instead of the original 15.

Rule B for saving diodes

When two logical functions A and B are combined into a single logical AND function AB, the saving in diodes equals the number of occurrences of AB minus the number of blocking diodes which must be added to the matrix to isolate A and B from AB. There are three different possibilities under Rule B: Case 0, Case 1, and Case 2, the case number equaling number of blocking diodes required.

Case 0—When A and B both occur exclusively in the combination AB, the number of blocking diodes is zero and the diode gain equals the occurrences of AB. The application of Rule B, Case 0 is shown in Figure 3. The original matrix in Figure 3A has four occurrences of AB and requires eight diodes; that in Figure 3B uses only four diodes.

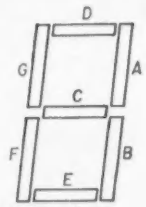
Case 1—When either A or B, but not both, occurs exclusively in the combination AB, the number of blocking diodes required is unity, and the diode gain equals the occurrences of AB minus unity. The application of this case is demonstrated in Figure 4. The original matrix, Figure 4A, uses eight diodes. Combining AB into one function produces the matrix in Figure 4B which requires six diodes, a saving of two.

Case 2—When neither A nor B occurs exclusively in the combination AB, the number of blocking diodes required is two, and the diode gain equals the occurrences of AB minus two. The example of this case is illustrated in Figure 5, with the number of diodes being reduced from nine to eight.

Rule C for saving diodes

Once a combined function AB is established, it can be considered as an independent logical function which can be further combined according to the previous rules and cases. Thus, if the combinations AB and CD both occur exclusively with each other, they can be combined in a function ABCD with a diode gain equal to the number of occurrences of ABCD. A limit on this type of combination is fixed, however, by the number of diodes that can be used in series in a particular application.

It is important to point out that if a combination AB leaves some functions A remaining, these remaining A functions cannot be considered as independent. They cannot now occur exclusively with any other function since diodes will still be required for blocking. On the other hand, if AB occurs exclusively with another function, its combination then falls under Case 0 since AB is an independent logical function with no further direct link to A or B. The



General display configuration

SIMPLIFYING A DISPLAY ENCODING MATRIX

FIG. 6. Decimal display using lighted or unlighted (binary) segments.

FIG. 7 (A)

	A	B	C	D	E	F	G
1	X	X					
2	X		X	X	X	X	
3	X	X	X	X	X		
4	X	X	X				X
5		X	X	X	X		X
6		X	X		X	X	X
7	X	X		X			
8	X	X	X	X	X	X	X
9	X	X	X	X			X
0	X	X		X	X	X	X

(B)

	8 A	9 B	7 C	7 D	6 E	4 F	6 G
8 A	7	5	6	4	3	3	
9 B		6	6	5	3	6	
7 C			5	5	3	5	
7 D				5	3	4	
6 E					4	4	
4 F						3	
6 G							

FIG. 8 (A)

	A	B	C	D	E	1 EF	1 BG	2 AD
1	X	X						
2			X			X		X
3		X	X		X			X
4	X		X				X	
5			X	X	X		X	
6			X			X	X	
7		X						X
8			X			X	X	X
9			X				X	X
0						X	X	X

(B)

	8 A	9 B	7 C	7 D	6 E	4 EF	6 GB	6 AD
8 A	1	1	0	0	0	1	0	
9 B		1	0	1	0	0	2	
7 C			1	2	3	5	4	
7 D				1	0	1	0	
6 E					0	1	1	
4 EF						3	3	
6 GB							3	
6 AD								

FIGS. 7 and 8. Figure 7A is the shorthand notation for the straightforward matrix representing the decimal display, Figure 6. Figure 7B tabulates the number times each output of Figure 7A appears and the number of times each output combines with others. From Figure 7B it is possible to pick optimum combinations of outputs and develop a second shorthand matrix as shown in Figure 8A. For this new matrix design outputs vs outputs are tabulated, Figure 8B.

FIG. 9A

	A	B	C	D	E	1 EF	1 GB	2 AD	2 C/BG	2 EF/AD
1	X	X								
2			X							X
3		X	X		X			X		
4	X								X	
5				X	X				X	
6						X			X	
7		X						X		
8									X	X
9								X	X	
0							X			X

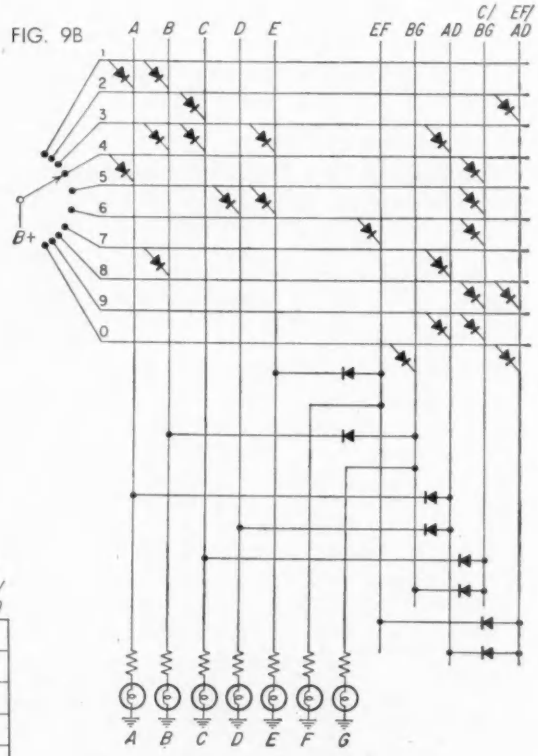


FIG. 9. The optimum matrix is shown in Figure 9A and the corresponding wiring diagram in Figure 9B. This matrix uses 31 diodes compared with 47 in the original design, Figure 7A.

blocking diodes, which were added when AB was formed, serve to maintain it independent of A and B.

Applying the Diode Saving Rules to a Display Encoding Matrix

The repetitive evaluation method with its accompanying rules and cases will now be applied to a relatively large encoding matrix such as would be used to produce the decimal digits 0 through 9 by lighting appropriate segments of the rectangular decimal display shown in Figure 6. The corresponding matrix, based on a straightforward design approach with no combined logical functions, uses 47 diodes. A shorthand notation for this matrix is shown in Figure 7A. An X represents a diode connection from input to output leads. An input voltage applied to any one of the input lines will energize the appropriate display segments to produce a decimal digit corresponding to the input value.

Initial diode reduction

The first step is to scan Figure 7A to determine the number of times that outputs occur in combination with each other and tabulate the results as in Figure 7B. The numeral in each square in Figure 7B represents the number of times that the coordinates occur in combination with each other. Thus, A and D occur together six times. Numerals outside the triangle represent number of occurrences of each output. D occurs seven and A eight times.

Since AD occurs six times, D seven times, and A eight times, neither A or D occurs exclusively in the combination AD. The diode saving by incorporating AD as a logical function is therefore calculated by Case 2: the diode gain is $6 - 2 = 4$.

The diode gain for each combination of two functions can be now systematically and rapidly determined from Figure 7B. Specifically:

Comb	Gain	Comb	Gain
AB	5	*CD*	3
AC	3	*CE*	3
AD	4	*CF*	1
AE	2	*CG*	3
AF	1	*DE*	3
AG	1	*DF*	1
BC	4	*DG*	2
BD	4	*EF**	3
BE	3	*EG*	2
BF	1	*FG*	1
*BG**	5		

An asterisk indicates an output occurring exclusively with the combination. If this combination is chosen to eliminate redundancy, only one blocking diode is required. The exclusively occurring output can be eliminated from any further output tabulations.

As an example in making up the above list, BG occurs six times, G six times, and B nine times. Therefore, G occurs exclusively in the combination BG although B does not. This puts the combination BG in Case 1 and the diode gain is $6 - 1 = 5$.

Maximum diode gains result from the following:

Comb	Gain	Comb	Gain
AB	5	*BE*	3
*BG**	5	*CD*	3
AD	4	*CE*	3
BC	4	*CG*	3
BD	4	*DE*	3
AC	3	*EF**	3

The combinations to be incorporated in the first revised matrix must now be selected. Although at first it appears ideal to choose those combinations which will yield the maximum diode gain, in general it is best to avoid combining the same output function in more than one combination at any one evaluation even though this means saving fewer diodes. Otherwise the calculated gain may be invalidated. (The exception to this rule is when a matrix displays a readily recognizable symmetry as in the case of a decoding matrix using complements.)

From the foregoing maximum gains list, and limiting the choice to combinations using each output once, one choice would be AB, CD, and EF to give a gain of 11 diodes. A better choice is the combinations BG, EF, and AD to give a gain of 12 diodes. The new matrix using the latter combinations is shown in Figure 8A. Above each combination is marked the case number under which the combination was formed, corresponding to the number of blocking diodes introduced by the combination. Note that since all F's and G's appear exclusively in their respective combinations, they no longer exist as separate output functions. Specifically, segment F is always lighted in conjunction with segment E and likewise G with B. This matrix now requires 35 diodes, including blocking diodes, compared with the original, Figure 9A, using 47.

Improvement by repitition

Repeating the procedure will indicate whether more than 12 diodes can be saved. Outputs vs outputs from the revised matrix, Figure 8A, are tabulated in Figure 8B. Note that the original functions are considered as appearing the same number of times as in the original. This avoids errors in determining exclusive occurrences under Rule C.

Calculation of diode gains from Figure 8B for various combinations yields:

Comb	Gain	Comb	Gain
AB	−1	→*C/GB*	3
AC	−1	→*C/AD*	2
A/GB	−1	*DE*	−1
BC	−1	*D/GB*	−1
BE	−1	*E/GB*	−1
B/AD	0	*E/AD*	−1
CD	−1	→*EF/GB*	1
CE	0	→*EF/AD*	1
→*C/EF*	1	→*GB/AD*	1

These are all logical AND functions, the slant merely

SIMPLIFYING A DECODING MATRIX

	(d) A	($\bar{d}$) B	(c) C	($\bar{c}$) D	(b) E	($\bar{b}$) F	(a) G	($\bar{a}$) H
0	X		X		X		X	
1	X		X		X			X
2	X		X			X	X	
3	X		X			X		X
4	X			X	X		X	
5	X			X	X			X
6	X			X		X	X	
7	X			X		X		X
8		X	X		X		X	
9		X	X		X			X

FIG. 11. Shorthand notation for straightforwardly designed decoding matrix shown in Fig. 10.

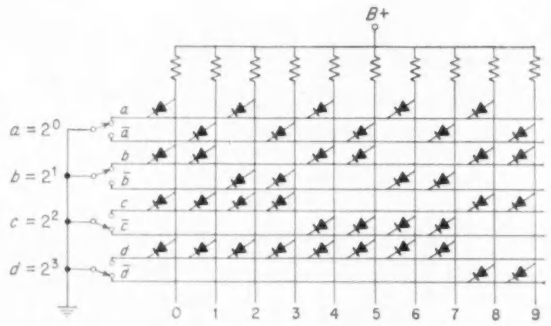


FIG. 10. Decoding matrix, straightforward design.

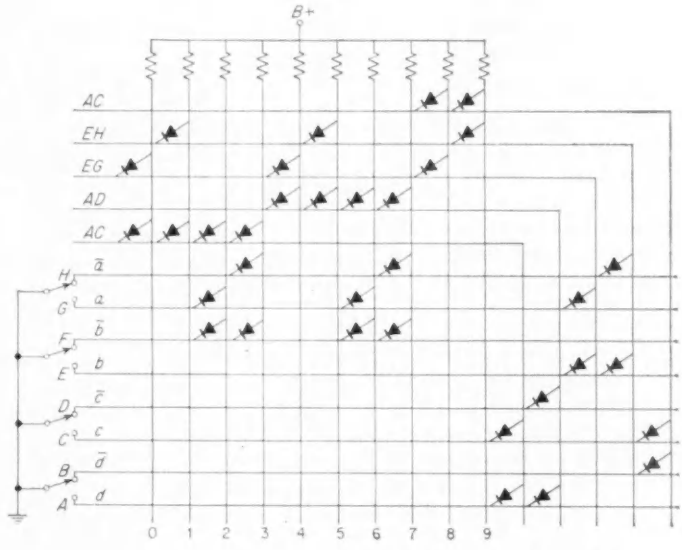


FIG. 12. Decoding matrix of Figure 10 reduced to 32 diodes.

being inserted to show, for instance, that *A/GB* is the combination of *A* AND *GB* and not *AG* AND *B*. The combinations of greatest diode gain are denoted by the arrow.

The largest gain results from using *C/GB* and *EF/AD*, saving four more diodes. The resulting matrix tabulation is shown in Figure 9A, the new matrix requiring only 31 diodes compared with the original 47. Repeating the procedure shows that no further gain is possible using the repetitive evaluation method. The actual matrix wiring, Figure 9B, is readily apparent from the final tabulation, Figure 9A. Again the X's represent a diode connection between input and output leads, and the numbers on top of the tabulation are the number of isolating diodes required between the combination and its constituent functions.

Applying the Diode Saving Rules to a Decoding Matrix

In applying the method to a decoding matrix, the matrix is "reversed" so it can be treated as an encoding matrix. The outputs in the original matrix are handled as if they were inputs to an encoding matrix.

The decoding matrix, Figure 10, requires 40 diodes in the straightforward design shown. The inputs are four pairs of complements: $\bar{a}$, a; $\bar{b}$, b; $\bar{c}$, c; and $\bar{d}$, d. By reversing this matrix and considering it as an encoding matrix in which there are ten input leads (0 to 9) and eight outputs (A through H), the shorthand notation for the matrix can be written as shown in Figure 11. Applying the same technique as shown for the encoding matrix results in a final matrix using only 32 diodes as shown in Figure 12.

Speed Control Methods for Dc Motors

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One of the most valuable characteristics of the dc motor is its ability to provide a wide range of easily adjustable speeds. This benefit has made dc motors of all types of particular interest to control engineers. Series, shunt, and compound motors in combination with packaged rectifiers and controls serve as actuators in systems from the lowest to the highest orders of automaticity. This discussion covers the fundamental speed, torque, and horsepower relationships for dc motors. The feature of the presentation is a single chart (next page) summarizing the 12 control circuits that form the basis of most of the packaged dc drives available today.

Fundamental equations

When a dc motor is operating, there is generated in its armature winding an emf E_c that acts in opposition to the impressed voltage V. Being a speed voltage (i.e., a voltage that depends upon the speed of rotation), this counter emf is directly proportional to the rate at which flux is cut by the armature conductors. Moreover, E_c is always less than the terminal voltage by the amount of the I_AR_A drop. Thus:

$$E_c = V - I_AR_A = k_1\phi S$$

where I_A = armature current
R_A = armature resistance
ϕ = flux per pole
and S = armature speed, rpm

Solving for speed:

$$S = k\frac{E_c}{\phi} = k\frac{V - I_AR_A}{\phi}$$

This equation indicates that the speed of a dc motor may be controlled by changing either counter emf or flux. The means for doing this include:

1. By varying a rheostat in series in the armature circuit. This lowers the voltage across the armature terminals and reduces the speed as the value of the resistance is increased.
2. By varying a rheostat in the shunt-field circuit of a shunt or compound motor. Raising resistance reduces field flux, increases motor speed.
3. By varying the voltage across the terminals of a series motor or by varying the voltage across the armature terminals of a shunt or compound motor while the shunt-field flux is maintained at a constant value by a separate source. Speed is lowered with diminishing values of voltage.
4. By varying a rheostat shunted across the armature terminals of a series motor. Reducing the ohmic value of the shunted resistor increases the series-field flux and decreases motor speed.
5. By varying a rheostat shunted across the armature terminals of a shunt or compound motor while another resistance, connected in series with the paralleled combination of armature and shunted resistor, is kept at some fixed value. This introduces an artificial IR drop in the armature circuit (across the series resistor) to decrease the motor speed as the ohmic value of the shunted resistor is reduced.

Torque and horsepower relationships

The torque of a dc motor is directly proportional to both armature current I_A and flux per pole ϕ, or:

$$T = kI_A\phi$$

The horsepower output is, on the other hand, proportional to both torque and speed. Thus:

$$\text{Hp} = kTS$$

These equations, indicate that for a given armature current I_A (rated value, for example):

1. If a speed adjustment is made by changing only the voltage impressed across the armature terminals, torque remains constant while the horsepower output varies directly with the speed. In the accompanying table, *constant-torque, variable-horsepower* speed control methods are illustrated in I-A and I-D for the series motor, II-C and II-D for the shunt motor, and III-D for the compound motor.
2. If a speed adjustment is made by changing only the flux, torque varies and the horsepower output remains constant. Thus:

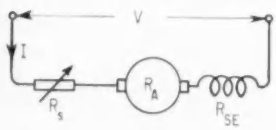
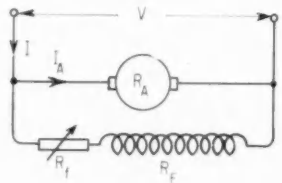
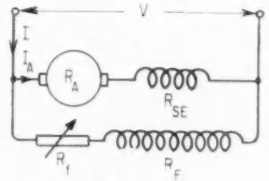
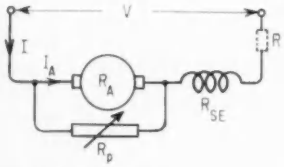
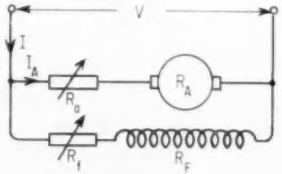
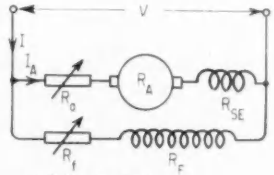
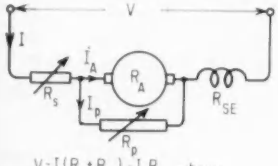
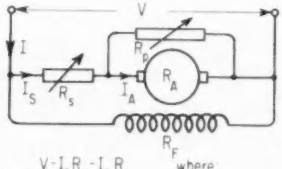
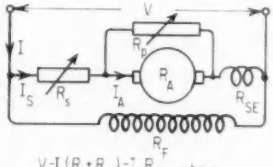
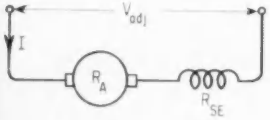
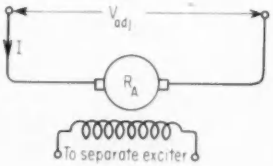
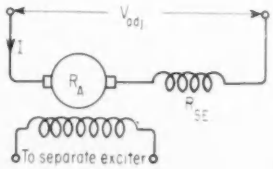
$$\text{Hp} = kTS = k\,[k\,\phi I_A]\left[k_2\frac{V - I_AR_A}{\phi}\right] = k'$$

Variable-torque constant-horsepower speed control methods are illustrated in the table by II-A for the shunt motor and III-A for the compound.

In connection with the variable armature-voltage method of speed control, it should be pointed out that for extremely heavy loads, i.e., those that cause the I_AR_A drop to become an appreciable part of the numerator ($V - I_AR_A$) of the speed equation, voltage changes have a diminishing effect upon the range through which the speed may be adjusted.

Several of the speed control schemes illustrated in the composite table employ adjustments of both flux and the armature voltage. In I-C for the series motor, for example, a decrease in the resistance R_p results in an increase in the current through the series field and the series resistance R_s. As a direct result the flux increases, the voltage drop $I(R_s + R_{SE})$ increases, and the voltage across the armature V_A diminishes. This combination of changes produces a marked reduction in speed. Other speed-control schemes may be similarly analyzed.

CONTROL CIRCUITS FOR DC MOTORS

Controlled Element	I SERIES	II SHUNT	III COMPOUND
A - Field Resistor	 $S = k\,\frac{V - I(R_s + R_A + R_{SE})}{\phi}$ Increasing R_s decreases speed	 $S = k\,\frac{V - I_A R_A}{\phi_{var.}}$ where: $I_A = I - V/(R_f + R_F)$ Increasing R_f increases speed	 $S = k\,\frac{V - I_A(R_A + R_{SE})}{\phi_{var} + \phi_{SE}}$ where: $I_A = I - V/(R_f + R_F)$ Increasing R_f increases speed
B - Field and Armature Resistors	 $S = k\,\frac{V - I R_{SE} - I_A R_A}{\phi}$ where $I_A = I - \left[\frac{V - I R_{SE}}{R_p}\right]$ Decreasing R_p decreases speed. A current-limiting resistor R is sometimes connected in series with R_{SE}	 $S = k\,\frac{V - I_A(R_a + R_A)}{\phi}$ where: $I_A = I - V/(R_f + R_F)$ Increasing R_a decreases speed. Increasing R_f increases speed	 $S = k\,\frac{V - I_A(R_a + R_A + R_{SE})}{\phi_F + \phi_{SE}}$ where: $I_A = I - V/(R_f + R_F)$ Increasing R_a decreases speed. Increasing R_f increases speed
C - Series and Shunt Armature Resistors	 $S = k\,\frac{V - I(R_s + R_{SE}) - I_A R_A}{\phi}$ where: $I_A = I - I_p$ and $I_p = \frac{V - I(R_s + R_{SE})}{R_p}$ Increasing R_s decreases speed. Decreasing R_p decreases speed	 $S = k\,\frac{V - I_S R_s - I_A R_A}{\phi}$ where: $I_S = I - V/R_F$ and $I_A = I_S - \left[\frac{V - I_S R_S}{R_p}\right]$ Increasing R_s decreases speed. Decreasing R_p decreases speed	 $S = k\,\frac{V - I_S(R_s + R_{SE}) - I_A R_A}{\phi_F + \phi_{SE}}$ where: $I_S = I - V/R_F$ and $I_A = I_S - \left[\frac{V - I_S(R_s + R_{SE})}{R_p}\right]$ Increasing R_s decreases speed. Decreasing R_p decreases speed
D - Terminal Voltage	 $S = k\,\frac{V_{adj} - I(R_A + R_{SE})}{\phi}$ Increasing V increases speed	 $S = k\,\frac{V_{adj} - I R_A}{\phi}$ Increasing V increases speed	 $S = k\,\frac{V_{adj} - I(R_A + R_{SE})}{\phi_F + \phi_{SE}}$ Increasing V increases speed.

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Mechanical Control Cams

THE GIST: The mechanical cam can boast of a long heritage in automatic control. It should be given credit for making possible the first stored program systems and for serving as the earliest function generator. Today, of course, it is overshadowed by newer components, especially those in the electrical-electronic field. This fact, plus the widespread indifference of control engineers toward the older, more commonplace techniques of mechanical design, have made the cam a comparatively rare component in control systems. In this series of two articles, the author pleads the case for the use of cams in control systems, emphasizing their benefits of economy, simple design, accuracy and long life. Then, recognizing the fact that control engineers may avoid cams because they have forgotten how to design them, he presents a capsule review of basic design principles.

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The heavy emphasis on electrical-electronic techniques in present-day control engineering has created a situation wherein designers tend to neglect some proven and dependable components from other fields. In choosing a function generator, for example, the designer almost invariably considers only electrical types and seldom gives a thought to the mechanical cam. Yet the latter, which was the original function generator, offers many advantages that certainly justify its consideration in a greater number of cases. It is recognized, of course, that control engineers have in general allowed their knowledge of cam design to fade over the years. However, this alone should not deter wider cam use since the required design techniques are straightforward and easily reviewed.

Considered as function generators, cams provide the benefits of requiring less design effort and making possible the mechanization of discontinuous and jagged-shaped functions. Cams can implement mathematical relationships and functions that resist computation. Although they are difficult to fabricate, their use for computation is often justified because of the superior accuracy attainable. Cams have an advantage over electrical devices in that they are nondrifting, yield long sustained accuracy, require less maintenance, and provide greater reliability and durability. Cam computer machinisms are sometimes much lighter in weight than their electrical counterparts. Thus, cams and cam surfaces as components of function generators seem to be practical for performing mathematical operations on much of the data that are obtained in the instrument and control industry.

Linearizing cams

Cams are often employed in measurement devices to linearize the follower movement. An example of such an application is where a quantity to be read on a scale is a nonlinear function of a measured variable. A cam interposed between the variable and the computed quantity can establish linearity between indicator motion and measured variable. Such linearization of a measurement or control is actually in the nature of a computational process. This is illustrated by a comparison of two types of flow meters operating on the differential pressure across an orifice. The basic equation is:

$$Q = CH^{1/2}$$

where Q = flow
H = differential pressure
C = constant depending on units

The orifice sets up a differential pressure that moves the diaphragm connected to a pointer or recording pen. The recorder chart is calibrated in units of flow. If the connection is direct, a nonuniform (square root) scale is needed because pen movements represent head differential, while flow is the quantity sought. An obvious disadvantage of the square root chart is that the divisions are small at low flows and large at high flows. Figure 1A shows a cam and follower interposed between the diaphragm and the pointer. This cam and follower extracts the square root of the differential pressure so that an evenly divided indicator dial, Figure 1B, can be used. The exponent of the cam function may have any value dictated by the application.

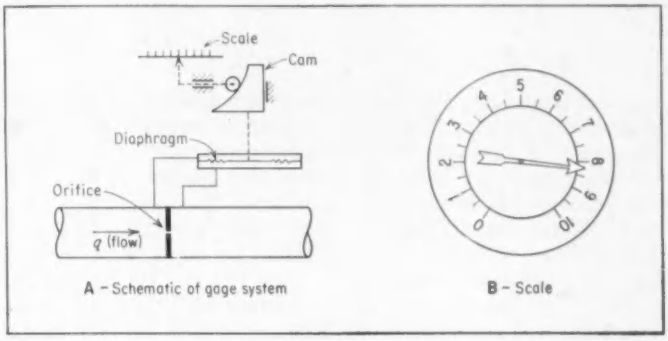


FIG. 1.
Flow measurement using cam to linearize pressure differential for direct reading uniform scale.

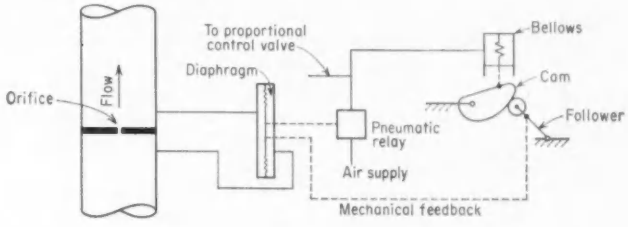


FIG. 2.
Schematic diagram of cam-linearized force-balance arrangement for flow measurement.

As a step beyond pure measurement and indication, function cams can be used to linearize or nonlinearize the operation of a control actuator. For example, cam drives can regulate a damper or valve controlling the flow of liquids or gases. Because the position of the damper or valve does not have a linear relationship to flow rate, the cam positioner serves to provide coordination between input signal and flow. In Figure 2 differential pressure acts on a diaphragm with a force proportional to the square of the flow rate. This force is transmitted to the outside through a stuffing box and controls a relay valve which produces a pressure on top of a spring-opposed bellows diaphragm. For every pressure on the bellows, a stroke is obtained which is modified by a cam and reconverted into a force that finally opposes the primary flow rate signal. Thus, mechanical feedback establishes a balance between forces and produces a pressure which by use of a proper cam can be made directly proportional to flow. Since the cam is the connecting link, it is a simple matter to change the travel needed to cancel out bellows force resulting from a given signal.

Cams are particularly advantageous when control system signals do not follow any predictable or simple mathematical relationship to the regulated quantity. In such cases it is possible either to adopt an adjustable cam which can easily be made suitable in the field or to actually shape the cam in the field. Any relationship between input and output functions can thus be produced.

There are occasions in control design where it is necessary to develop an electrical output that is some complex function of a nonlinear mechanical input. A very satisfactory solution to this problem is to interpose a cam between the input and a linear potentiometer, which is a dependable and widely available component. More complex devices can be constructed based on this same approach. A good example is the addition of a drive cam to a variable core transformer. The resulting electrical signals are thereby modified by the configuration of the cam.

One of the most fertile fields of application for the cam is that of the analog computer. Here cams perform mathematical operations, make possible mechanical adjustments for maintaining precision of the system, amplify small motions and forces, and serve as information storage devices.

Design factors

A first and important step in cam design is the selection of the scale. The input scale is fixed by the fact that the cam usually rotates less than 360 deg for the full range. The output scale or slope, on the other hand, offers unlimited opportunities for choice. From the standpoint of accuracy, it is desirable to have the scale as large as possible; i.e., a minimum rise per inch of periphery per revolution. If this rule is observed, backlash and dimensional accuracy have lesser effect.

The second step is to establish cam size and the sense of the follower movement. The latter refers to the direction of movement, outward or inward, for increasing values of rotational angle. The steepest portion of the function curve should be at the cam outer radius, permitting the use of smaller cams for the same pressure angle limit. Generally, a maximum pressure angle (the angle between the cam slope and the follower axis) of 30 deg is suggested, but angles as high as 45 deg have been successfully employed. In addition, the control

engineer should guard against the possibility of excessive wear or undercutting. This detrimental condition may be alleviated by increasing cam size or reducing the output scale. In general, the designer can feel free to specify close manufacturing tolerances, on the order of plus or minus 0.0002 in. and 2 min of arc, or better. Figure 3 shows a group of high accuracy computer cams.

The basic function or motion relationship between related parameters X and Y is:

$$Y = F(X) \tag{1}$$

The variable X may be called the input parameter and Y the output parameter. $F(X)$ is any single-valued continuous function whose derivative is held within certain limits to prevent the resulting cam from being impractically large. Among the many mathematic operations that can be implemented are squares, roots, reciprocals, empirical functions, and trigonometric functions. A cam, for example, can be designed to produce an output proportional to the tangent of the cam angle. Even nonmonotonic functions (those having two possible values of Y for each value of X) can be mechanized by means of two cams rotating in synchronism.

Figure 4 shows some of the more popular cam mechanisms, including a group of nonpositive drive types that are held in contact by springs (not detailed). The first is the general case of two contour cams in purely rolling contact. The same type of action can often be provided by a noncircular gear which consists of cam pitch lines with teeth. In Figures 4B and 4C, input X is depicted as radial cams, output Y as translating and oscillating followers. Figure 4D provides a rotating spiral for input X with a positive drive pin engaging the groove for output Y. Figure 4E shows a gear cam which is similar to Figure 4D except that the output parameter Y is a rotating pin gear meshing with grooves in the spiral input. The primary advantage of these spiral cams is that more than one cam revolution can be provided for high accuracy. Spirals having as many as eight revolutions have been used. One of the difficulties is that the spirals require rather liberal separation depending on the function involved. Figure 4F shows a rotating cylindrical cam input having a translating output. Cylindrical cams generally have a smaller maximum dimension than does an equivalent radial cam.

Figure 4G differs from all the others in that it is a three-dimensional cam or camoid with two degrees of freedom. Input and output parameters X_1 and Y translate, while input X_2 rotates. In an alternate design, all parameters may have rotational action. The follower is often a spherical ball in contact with the cam profile. The camoid function is expressed as:

$$Y = F(X_1, X_2) \tag{2}$$

The techniques and applications described in the following sections for nonlinear function generators are representative only. Care should be taken in

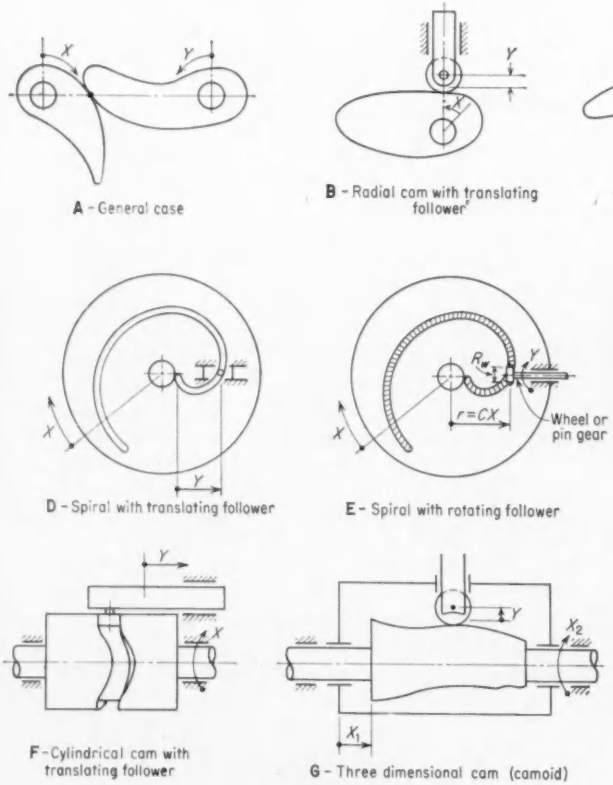


FIG. 4.
Collection of common types of control cams.

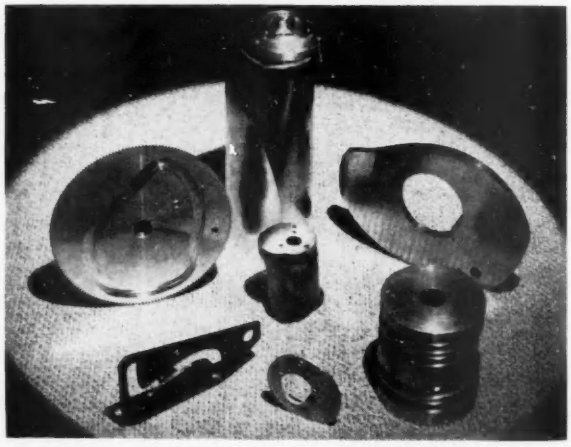


FIG. 3.
Variety of high-precision cams.
Courtesy of Ford Instrument Co.

choosing the most suitable technique and in optimizing parameters for a given problem. Often a combination of the various methods can be used where a high degree of nonlinearity is required.

Step cam—time program controller

Today's automatic machinery and processes commonly involve complex operating programs of a time-based nature. One of the simplest control programmers is the synchronous interval timer, Figure 5, in which a motor drives a cam at a constant speed. The mercury switch or mechanical contact is actuated at the instant of time determined by the cam design and shaft speed. Multiple timers, which have several cams arranged on one shaft to actuate a corresponding number of switches, provide an added feature in that adjustments can be made in the time relationships among pulses produced by the various cams. In addition, multiple timers can be equipped with adjustments for permitting changes to different switching patterns. Two adjustable cams are provided for each switch, one governing the beginning and the other determining the end of the actuating portion of the cycle. Cams obviously may be employed not only to switch something on or off but also to generate signals of predetermined amplitude and slope.

Despite the fact that time is inherently a digital quantity, a simple cam timer is analog in character. However, digital and analog techniques can be mated to yield a simple, high accuracy, versatile class of controllers distinguished by the term "two-speed". Figure 6 shows a typical unit, which is a special mechanism superimposing the motions of cams A and B. Cam A is the main drive cam locating the follower position in steps, and cam B is the higher speed cam giving the follower its back-and-forth cycle for each position. As shown in Figure 6B, cam B turns at least eight times as fast as cam A. The translating motion cycle can be altered by varying the relative speed ratio of cams A and B. Any combination of motions is possible. The follower actuates a switch or contact spring when both are in the extreme position.

The same type of action can be achieved by gliding contacts or brushes on conducting cam paths, Figure 7. The cams rotate at different speeds, with the fast discs determining both the beginning and end of the switching function. This program controller or timer is compact, simple, and accurate and can be compounded to accommodate a number of output channels.

Cylindrical cams

The radial or cylindrical cam employing an oscillating follower is perhaps the simplest computer element employed in measuring systems. Simple polynomial expressions are the most common functions, although any relationship between cam rotation and follower displacement is possible. The polynomials are of the form

$$y = C\theta^n$$

The nomenclature listed here applies to Equation 3 and the discussion that follows:

θ = cam angle of rotation for displacement y
n = any value
c = constant
h = maximum follower output rise
β = angle of cam rotation for rise h
y = output

The value of n depends upon the system under investigation and is typically $\frac{1}{2}$, 1, or 2. For $n = 1$, the resulting straight line cam resembles an Archimedes spiral for which a linear input-output relationship exists of the form

$$y = \frac{h\theta}{\beta}$$

In an illustrative example, an open channel may have a triangular weir, Figure 8A, for measuring water flow. The actuating mechanism is a float

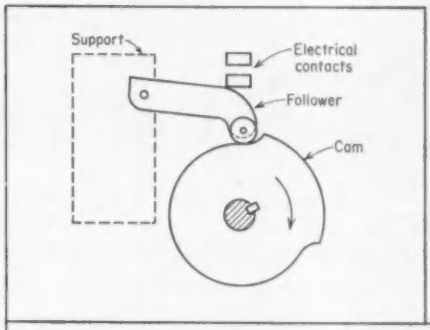


FIG. 5

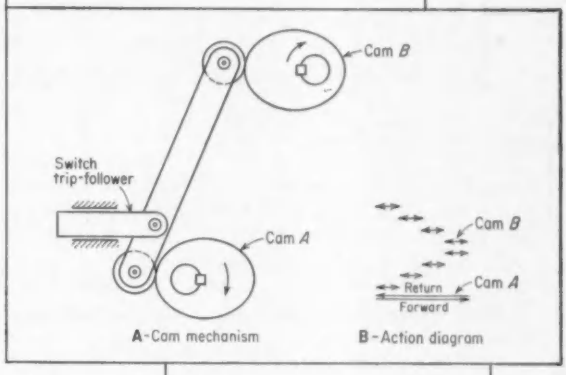


FIG. 6

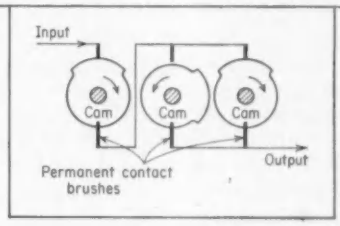
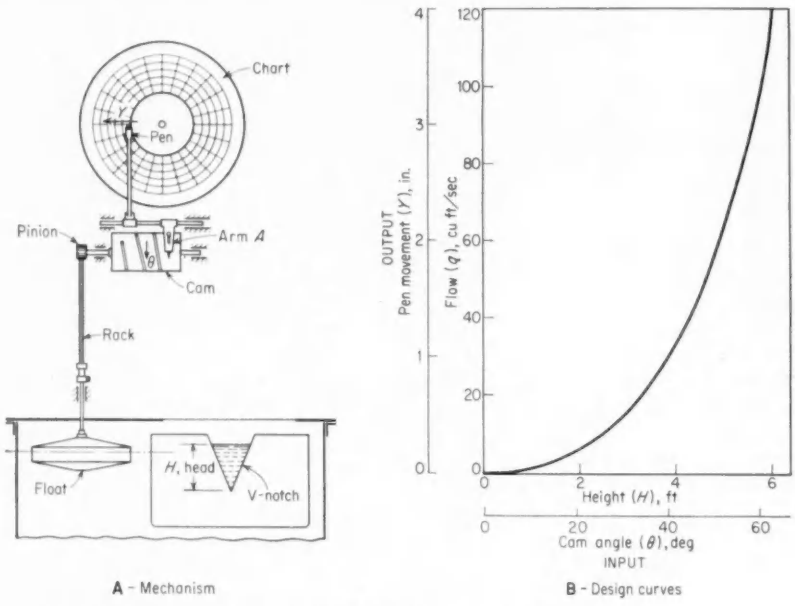


FIG. 7

FIG. 5. Synchronous timer with cam-operated switch.
FIG. 6. Cam with controled translating cycle.
FIG. 7. Two-speed principle applied to brush contact timer. The cams are constructed of conducting material.



A - Mechanism

B - Design curves

FIG. 8. Flow meter and chart used as basis for cam design.

which moves directly as the head varies. Because the flow does not vary linearly with head, a cam is used to make the necessary conversions. A rack on the float rod meshes with a pinion to turn the cam with the recording pen and arm A attached as shown. The translational drive is by means of a pin on arm A riding in the cam groove. The cam follower moves linearly with flow and so does the recording pen. Assume that the V-notch has a height of 6 ft and an included angle of 60 deg and that the chart scale is 4 in. long. The flow formula is $q = 1.45H^{2.47}$ where q is the flow (cu ft/sec) and H is the head in feet.

Figure 8B shows input H plotted against output q. If the diameter of the pinion meshing with the rack is 2 in., the number of cam revolutions for the total stroke of 6 ft is:

$$\frac{6 \times 12}{2} = 11.4 \text{ radians} = 655 \text{ deg}$$

which is an acceptable figure. In Figure 9B there is also presented a plot of pen displacement Y against the angle of cam rotation θ. The cam can now be drawn to scale and the pertinent factors of size, pressure angle, curvature, undercutting, groove spacing, etc. considered. A different pinion size may be necessary.

An alternate mechanism has been commercially employed using a radial cam and larger gears since all radial motions are limited to less than 360 deg rotation. Change gears are also available for different maximum heads and capacities.

Archimedes spiral gear cam

An example is now presented to show how an Archimedes spiral cam similar to that of Figure 4E can be designed to give a square relationship between the input and the output. This mechanism is an excellent computing tool with accuracies as high as 1 part in 30,000. Assume that the Archimedes spiral input (parameter X) is rotating clockwise and driving a pin gear (parameter Y).

Let

X = input cam angular rotation, rad
Y = output follower angular rotation, rad
R_w = mean radius of pin wheel, in.
r = instantaneous radial distance from center of cam, in.
C = a constant

From the figure

$$R_w\,dY = r dX$$

However, for the Archimedes spiral

$$r = CX$$

Therefore $$R_w\,dY = CX\,dX$$

or

$$Y = \frac{C}{R_w}\int_0^{X_1} X dX$$

$$= \frac{CX^2}{2R_w} \qquad (4)$$

since X_1 is any arbitrary end point. Therefore, the output is proportional to the square of the input cam rotation. It should be noted that offsetting the follower wheel from the cam axis would improve the force distribution of the mechanism. For the Archimedes spiral it can be shown that an offset equal to the lead per radian will permit the follower wheel to be tangent to the spiral at all points. The form of this spiral is an involute.

The limitation of the cam discussed occurs when successive turns allow insufficient clearance for the follower. This condition can be remedied by using several cams in series—the output of the first supplying the input to the second. For example, suppose the desired function is

$$Y = X^4 = (X^2)^2$$

This can be solved by compounding two squaring cams.

The second part of this article will discuss the design of the basic spiral contour cam, which is the most commonly used cam type in measurement, control, and computing equipment. Major attention also will be given to the application of cams as corrective devices, an area of use that is important to the designer of precision systems.

Keeping Sample Lines Hot

The success of a process stream analyzer system hinges on careful engineering and installation. A prime requirement in getting a representative sample from the process to the analyzer is to prevent condensation of high boiling point components. Here's how to heat sample lines by steam.

E. A. HOUSER
Beckman Instruments, Inc.

Stream analyzer sampling systems consist of three major categories: equipment at the process vessel or pipe for withdrawing a sample of the process stream, equipment for conditioning sample at the analyzer location, and sample line for transporting the sample from process to analyzer. Frequently, the sample proceeds from a hot environment at the process to a relatively cool environment at the analyzer. Unless proper steps are taken, the sample will cool and, if the process stream is a gas, high boiling components may condense, causing false analysis and clogging of lines and equipment.

In many analyzer installations it therefore becomes imperative to maintain the sample line and other equipment at suitably high temperature. A simple, safe, and economical way of doing this is by steam tracing. Essentially, steam tracing consists of heating the sample line by putting the sample line in close thermal contact with the steam line and by insulating both lines from the cooler environment.

To maintain the required sample temperature, careful attention must be paid to the details of design and construction of steam traced lines. Generally, no portion of the sample line can be left untraced in the hopes that the sample will carry enough heat to maintain its temperature. Insulation by itself is not sufficient. Liberal use of a heat transfer medium like Thermon (Thermon Mfg. Co., Houston, Tex.) is advisable between steam and sample lines.

There are six common methods for steam tracing sample lines, offering a compromise choice based on heat transfer efficiency, line support requirements, deterioration, and cost.

METHOD 1—TUBE-AND-TUBE

Two lines of metallic tubing, usually of equal small diameter, are strapped together with wire at close intervals and insulated overall. This method offers little inherent rigidity and thus requires support at frequent intervals. Although tube-and-tube is less expensive than other methods, it is not as effective. The tubes tend to separate under vibration and temperature effects, so that the heat transfer area-of-contact is very small. Also line flexing causes the insulation to drop off, resulting in cold spots. The tube-and-tube method is suitable when the required sample temperature is relatively low compared with the available steam temperature.

METHOD 2—TUBE-AND-PIPE

In this method the smaller sample tube is strapped at intervals to ¼- or ½-in. diam steel pipe through which the steam is passed. The pipe provides the

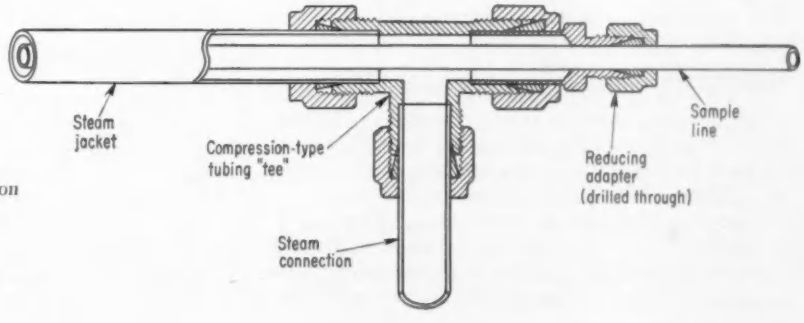


FIG. 1. Making steam connection for tube-in-tube steam tracing installations.

needed rigidity for longer runs between supports and provides a better base for insulation. While the heat transfer between the pipe and tubing is better than the tube-and-tube design, continuous insulation still is required to prevent sample condensation at cold spots.

METHOD 3—TUBE-IN-TUBE

Here the sample carrying tube is installed inside a larger tube carrying steam. Common combinations are $\frac{1}{8}$ inside $\frac{3}{8}$, $\frac{1}{4}$ inside $\frac{1}{2}$, and $\frac{3}{8}$ inside $\frac{3}{4}$. Tube-in-tube offers the advantage of surrounding the sample tube entirely with steam, protecting the heat transfer efficiency from insulation deterioration by wear, weathering, and vibration. The entire assembly can be bent smoothly, eliminating such installation troublemakers as pockets, corners, and threaded connections. Lengths up to 50 ft can be handled easily, particularly if both tubes are soft copper or aluminum. Using bored-through compression-type tubing fittings, Figure 1, facilitates making end connections. The major disadvantage of the tube-in-tube method is that it requires frequent support because of its lack of mechanical strength.

METHOD 4—TUBE-IN-PIPE

Tube-in-pipe is stronger than tube-in-tube construction but more difficult to install because of the required extra fittings at bends. The rigidity of tube-in-pipe prolongs insulation life and requires less support along the run. Connections are similar to that shown in Figure 1 for tube-in-tube, except that pipe tees and bored-through tube-to-pipe fittings are used instead of all-tube fittings.

METHOD 5—PIPE-IN-PIPE

Better known as steam jacketing, this method is best for permanency and structural strength but is also the most expensive to install. Pipe-in-pipe requires a considerable amount of field welding, particularly where routing the lines calls for a large number of bends. Pipe-in-pipe construction also results in the greatest exposure of nonjacketed sample line at each bend. Care must be taken at these points to avoid cold spots. A recommended method for maintaining sample temperature at corners uses at least two loops of steam jumper, one above and one below the sample pipe, to heat the corner bend. The entire corner must be liberally packed with a good heat transfer medium and then insulated.

METHOD 6—MULTIPLE BUNDLED TUBING

Several manufacturers produce metallic tubing in bundles having abrasion- and corrosion-resistant outer jackets. One type has a spiral metal covering similar to BX electrical cable. Multiple bundled tubing can be conveniently used as steam traced sample line by passing steam through one or more tubes and the sample through another, with remaining lines as spares. Such an arrangement does not need additional insulation in moderate climates or for low temperature samples. While one of the most economical installations, the multiple bundles are not available with stainless steel tubing.

Precautions for sample lines

Regardless of the method chosen for steam tracing, the best installation will suffer if the steam passage constricts or fills with condensate. Care must be taken to supply traced lines with dry steam and adequate traps to withdraw condensate. Steam should flow downward from the steam source. If low points are unavoidable, a trap is required at each point. For long runs it is advisable to sectionalize the line for steam tracing purposes and supply steam from various points along the run. When headers are not available to supply steam to the traced line, it is desirable to install a 1-in. or larger insulated and trapped header.

Frequently overlooked is the requirement for steam tracing the sample vent lines from analyzers. Sample vent lines, usually kept separate from plant flare lines and blowdown systems, generally consist of $\frac{3}{8}$-in. OD tubing run to a suitable elevation, with the upper end of the tube inverted to point downward. Because of its higher elevation and exposure to winds, the line's upper end is usually colder than the lower. This leads to a good possibility of condensables collecting at a low point of the sample vent line and causing a varying back pressure on the analyzer. Such instruments as infrared analyzers, colorimeters, and chromatographs are sensitive to pressure changes in direct proportion to the absolute exhaust pressure. Each 4 in. of water column change in pressure is equivalent to a 1 percent change in analyzer readout. Thus, condensed liquid in a vent line can easily introduce several percent noise level in the analyzer's readout. Avoidance of this conden-

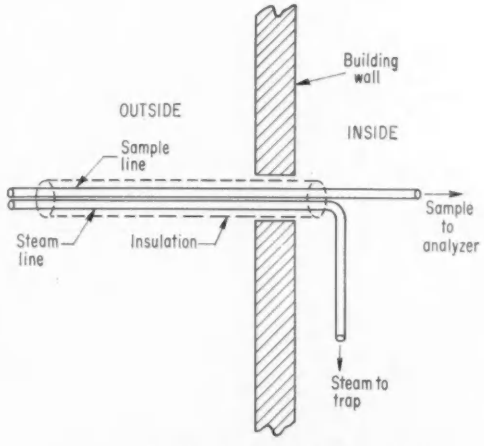


Fig. 2—To ensure complete steam tracing of sample line, bring the steam line into the analyzer enclosure.

sation problem calls for installing a manometer-type leg for draining condensables when they occur or steam tracing the vent line to prevent condensation in the first place.

Consideration must also be given to the points at which sample lines enter and leave heated rooms and enclosures in which the analyzer is mounted. An entry point through a metal enclosure wall via a bulkhead union is usually cold because the box wall carries heat away from the bulkhead union. To overcome this cold spot problem, it is imperative to bring the steam line as close as possible to the enclosure wall. The preferred way is to wrap several loops of small diameter steam tubing around the bulkhead fitting and pack the entire assembly with Thermon-type material. Entry points through instrument house or control room walls should be made as shown in Figure 2, by continuing steam tracing inside the heated room.

Steam tracing sampling system components

In addition to its sample connection and sample line there are other components like valves, gages, and regulators functioning as integral parts of the sampling system. These components may also require heating to prevent condensation and serious change in sample composition indication. Two basic ways exist for heating these sampling devices. The first method is to heat each device individually by wrapping with steam tubing and insulating overall. The second method is to install all components within an insulated and heated enclosure.

With individual component tracing, extreme care must be taken to insure adequate heat transfer between steam tubing and the item being heated. Frequently a loose coil is wrapped around the component and the space between the coil and the component filled with heat transfer medium. Tubing unions should be associated with each component to avoid dismantling any more line than required to reach the component to be serviced. Thus, thought must be given not only to adequate steam tracing of the component but also to its future maintenance.

Care must be taken to trace all parts of every item carrying sample. Pressure gages, for example, can introduce serious changes in sample composition. If the Bourdon tube is unheated, part of the sample will condense and reflux back into the gage connection. Usually a loop of steam tubing clamped to the gage, covered by a material like Thermon, and then insulated, will prevent refluxing.

Small purge-type flowmeters of the type commonly used in sampling systems are difficult to steam trace. However, one successful method is shown in Figure 3. Here, a coil of small diameter ($\frac{3}{16}$-in.) tubing is mounted in the rear of the meter housing and the space between the coil and the flowmeter tube filled with a heat transfer medium. This arrangement has been found to maintain 100 percent water in the vapor phase using 25 psig steam even though the front of the tube is open to the atmosphere. Although it has not actually been tried, a single length of $\frac{1}{4}$-in. diam tube bent so it can lie against the flowmeter may also be adequate.

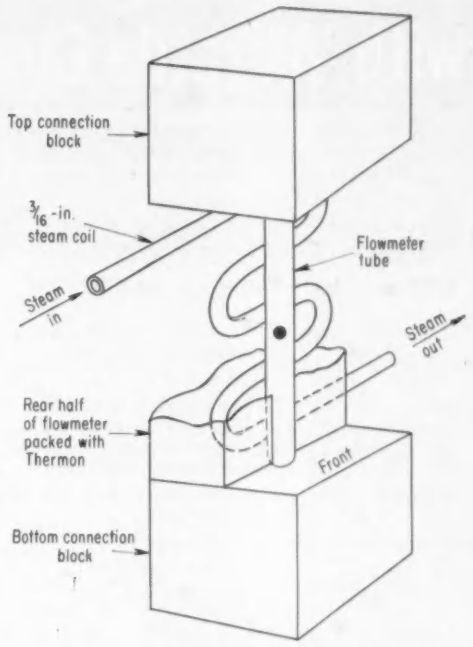


FIG. 3. Successful method for steam tracing a purge meter in analyzer sampling system.

Installing sampling system components in an insulated and heated box is preferred over the method of individual component steam tracing, particularly from the servicing standpoint, should one item require dismantlying for repair or replacement. One inch of fiberglass or slab magnesia is sufficient insulation for all but the coldest environment. The box internal temperature will depend on the heat exchange surface of finned heating coils and the quantity of air flowing past the coils. A heating system using an air jet blowing across the coils is considerably more efficient than stagnant air.

To protect the components from excessive temperatures, while still providing sufficient heating capacity and reserve steam pressure, requires some kind of box temperature control. Because of the small steam quantities used, a very small self-operated regulator would be desirable for this service, but such a device is not available. However, a $\frac{1}{2}$-in. size regulator with the smallest standard ports can do a creditable job. Also because of the small steam usage, it is very important to trap the supply line to the regulator as close as possible to the regulator. An adequate Y-strainer is advisable to prevent dirt from entering the regulator's valve port. Steam flow in the heating coils should be from top to bottom.

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Make Statistical Studies on Analog Simulations

WALLACE E. VANDER VELDE
GPS Instrument Co., Inc.

THE GIST: Analog computer simulations can be extremely valuable for determining the statistical characteristics of system performance. High speed simulation is important because a statistically adequate number of trials must be run in a practical time. All the special equipment that is required is available. Three separate approaches to a missile probability-of-kill problem show how it is used.

The performance of any system is limited ultimately by uncertainties in the operation of physical devices. These uncertainties usually can be known only in a probabilistic sense and must be treated by statistical techniques to determine their cumulative effects on performance. When the mathematical statement of a problem is linear, a well developed set of techniques is available for analysis, and a computer need not be used except to save time. But when the operation of a system is nonlinear to an important degree, very little theory is applicable, and recourse must be made to a simulation of the system and statistical study of simulation performance.

For statistical analyses, a simulation is best made on a high speed (compressed time) analog computer on which many problem solutions can be made in a short time. A large number of trial solutions is a characteristic requirement of statistical analyses; e.g., the statistical character of the error in a complex system can be determined from many samples of the error quantity (obtained by repeating the solution of the problem many times while it is influenced by the pertinent random variables). Typically a simulation which requires 30 sec for complete solution in real time can be solved 50 times per sec on the GPS high speed analog computer, and a sufficient number of samples for statistical analysis can be obtained in less than a minute.

Four items of specialized equipment are available to make simpler the use of the high speed analog computer for statistical analyses:

• A noise generator. The voltage across a gas diode in a magnetic field is amplified and filtered to get a probability distribution very closely approximating the normal distribution (Gaussian) and a nearly uniform power density spectrum from 20 cps to 200,000 cps. (Within the 3,000 to 1 time scale compression often used in high speed simulations on the GPS computer, the noise generator output represents white noise between 0.007 cps and 67 cps.) The noise generator includes a variable first order lag which can be used to shape the noise spectrum.

• An rms meter. The meter circuitry samples a random variable during the "on" time of the repeating solution and holds the average value during the reset time of the computer. A calibrated voltmeter indicates the rms value of the random variable.

• A probability distribution analyzer. This analyzer compares an input voltage e with a comparator level V at a selected instant in each solution of a problem and gates out a pulse to a preset digital counter if $e(t_s) \leqq V$. The ratio of the number of pulses from the comparator to the preset number of samples is the empirical measure of the probability that $e(t_s) \leqq V$. The comparator level V is taken as a dc voltage from a 10-turn potentiometer, which can thus be set successively to higher and higher values of V to determine the complete distribution function of the input voltage. A multiple channel analyzer could be set up to determine a complete distribution function in a single set of samples.

The missile probability-of-kill problem

The general class of control problems which has so far received most attention from the statistical standpoint is the evaluation of missile systems performance. The failure of a particular system to destroy its intended target is due to the initial conditions on the problem which are unknown in advance; the perturbations on the system during its operation such as thrust variations, winds, radar noise, etc.; and possible evasive maneuvering on the part of the target. All of these are by their nature predictable only in a statistical sense.

The most significant statistical measure of the effectiveness of a missile system is its probability of

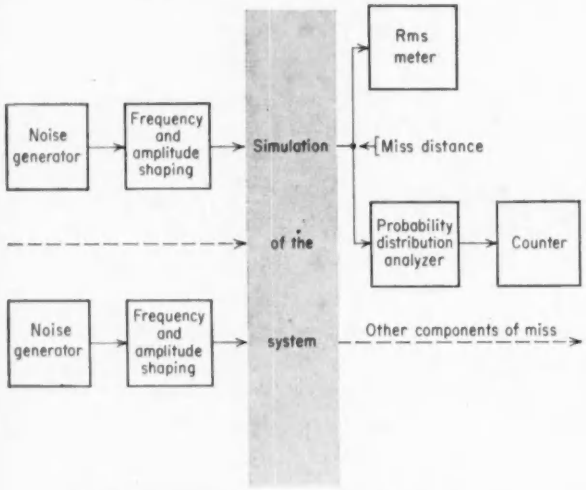


FIG. 1. Simplest instrumentation of missile performance problem produces probability distribution of distance by which missile will miss target.

kill. This involves two probabilistic considerations: the miss distance of the missile system is a random variable and, for a given miss distance, the question as to whether or not the target is destroyed according to some criterion is also answerable only in a probabilistic sense. Both can be treated simultaneously by the high speed statistical computer.

There are several approaches to problems in this class. The simplest is to simulate the missile system, introduce noise (shaped both in frequency and amplitude as necessary to obtain the correct power density spectrum and probability distribution functions) for each of the random influences to be considered, and monitor the error or miss on the rms meter and the probability distribution analyzer. This approach is diagrammed in Figure 1. The components of miss distance along different coordinate axes can be monitored separately if the system simulation is complete enough to generate them.

By comparing the rms miss distances or probability distribution functions for miss it may very well be possible to determine which of two systems is the better, even though the probability of kill against a particular target is not determined for either system. This is an economical and effective procedure for optimizing the loop gains and time constants of a system of given configuration. It will also serve as a quick estimate of the comparative effectiveness of systems of different configurations.

A more complete approach restricts attention to the component of miss along a single coordinate axis. The functional relationship of probability of kill to miss distance can then be expressed by a curve. The probability of kill of the system due to the single component of miss can be determined directly with a single test on the computer setup in Figure 2.

A simulation of the system with the appropriate noise inputs (representing the different random causes of miss) generates an ensemble of miss functions. The statistical effect of the probability of kill for a given miss distance is evaluated with the use of an additional noise generator and the probability distribution analyzer. The power density spectrum of the output of this additional noise generator is unimportant except that it must be broad enough so that the values of its output at successive sampling times are essentially uncorrelated. This noise is introduced at the input to the probability distribution analyzer as the signal e to be analyzed. The miss distance from the system simulation controls a function generator whose output is the comparator level V for the probability distribution

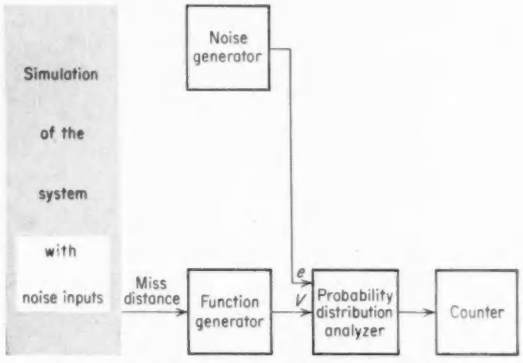


FIG. 2. One-dimensional solution of probability of kill adds to previous problem the distribution of kill probabilities as a function of miss distance.

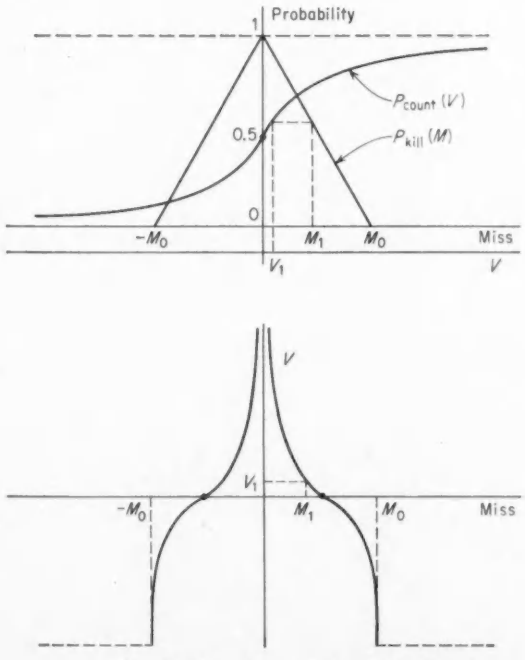
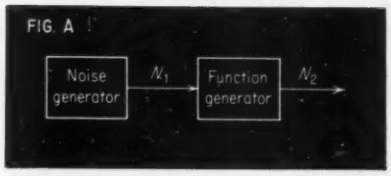
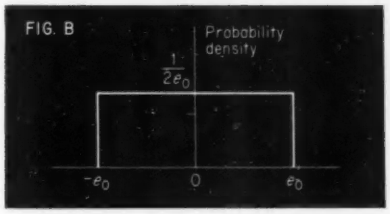
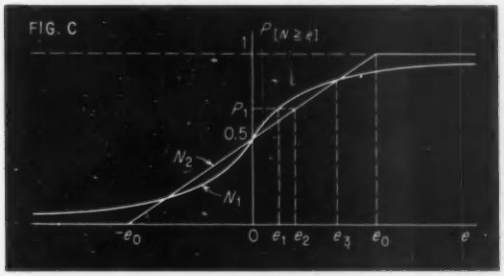


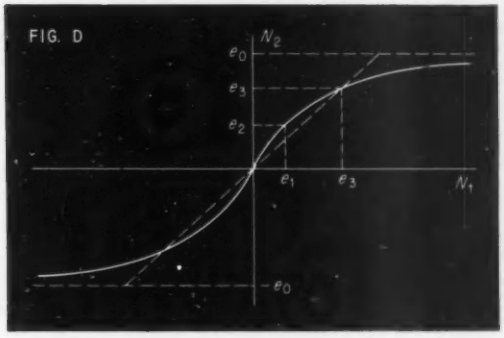
FIG. 3. The characteristic of the function generator in Figure 2 is determined as shown.

SHAPING A DISTRIBUTION FUNCTION







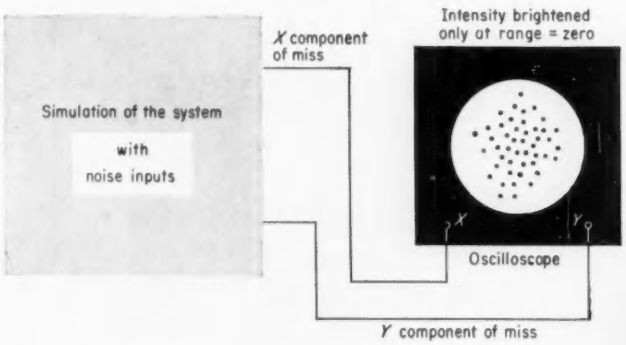


The output of the noise generator which has a normal distribution of amplitudes may have to be shaped in amplitude to yield a random variable having a probability distribution function corresponding to that of the uncertainty being simulated. This is readily accomplished using a function generator following the noise generator, as indicated in Figure A.

Consider the shaping of the output of the noise generator to yield a random process having a uniform probability density for amplitudes between minus e_0 and plus e_0, as shown in Figure B. The desired probability density function is integrated to yield the probability distribution function, which is plotted together with the normal distribution function corresponding to N_1, the output of the noise generator. The plot of distribution functions for this example is shown in Figure C. Now there is the probability P_1 that the random process N_1 will be less than or equal to e_1 as indicated by the distribution function for N_1. It is desired that N_1 have probability P_1 of being less than or equal to e_2 as indicated by the distribution function for N_2. This condition will be met if the function generator is set up such that the input e_1 yields the output e_2. Other pairs of input-output values are similarly determined by equating other values of probability on the two distribution functions. In this way the appropriate shaping function is determined. The function for this example is indicated in Figure D. This is a straightforward procedure which permits the output of the noise generator to be shaped to yield any desired amplitude distribution function.

analyzer. The function generator generates V as a function of miss distance such that the probability that e is less than or equal to V corresponds to the probability of kill for every value of miss distance. The probability distribution analyzer then gates pulses out to the counter with a probability corresponding to the probability of kill for the given miss distance.

In the operation of this problem, then, the computer simply solves the problem repeatedly, generating a particular value for miss distance on each solution. For each value of miss distance the probability distribution analyzer may put out a pulse to be counted—the probability of doing so being equal to the probability of kill for that particular value of miss distance. After a large number of runs the ratio of the number of counts to the number of runs is a direct measure of the probability of kill for the system. Using a problem repetition rate of 25 per sec for example, 1,000 runs can be made in



COMPUTER SET-UP

TARGET OVERLAY TO SCORE HITS

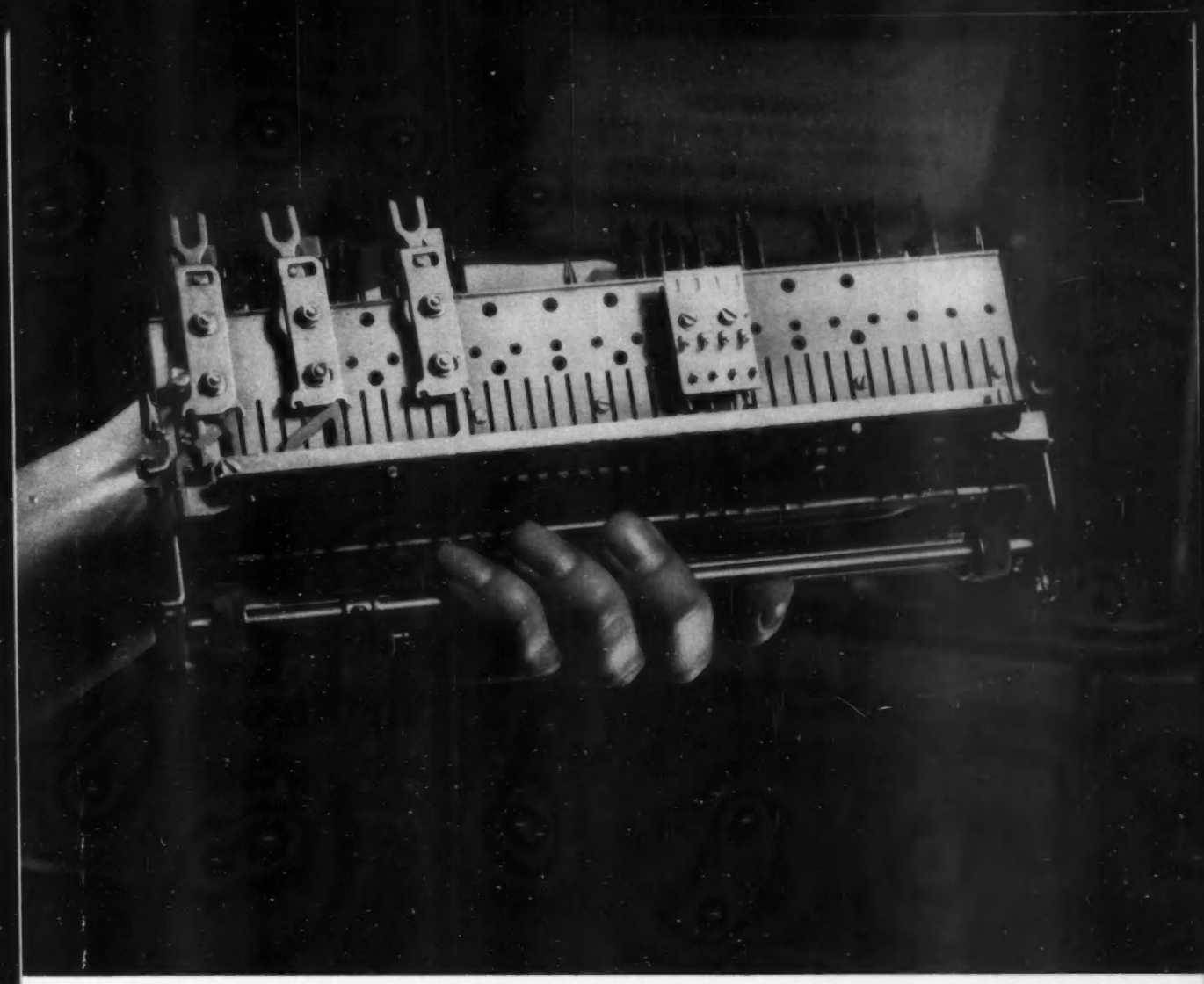
FIG. 4. The probability-of-kill problem can be solved for odd-shaped targets by using a properly sized overlay on a scope display of the miss dispersion pattern produced automatically by the computer.

less than 1 min, and the probability of kill is read directly from the counter with a proper placing of the decimal point.

The procedure for setting up the function generator for this problem is somewhat similar to that for shaping the output of the noise generator for an arbitrary probability distribution function (see box). The object is to obtain a functional relationship between miss and V such that for any miss the probability of getting a count is equal to the probability of kill. Consider a linear probability-of-kill dependence on miss as indicated in Figure 3. On the same set of coordinates, plot the probability of getting a count as a function of V. Since the output of the noise generator has a normal distribution, this latter curve will be the normal distribution function. Now for any value of miss such as M_1, determine the probability of kill by referring upward to the P_{kill} curve. Then by referring to the P_{count} curve at the same value of probability, read the required value of V, which is V_1. By determining enough pairs of points in this way, the proper relationship between miss and V can be found. In this example the analytically correct value of V for $M = 0$ is plus infinity, and the value for $M \geqq M_0$ is minus infinity. These values would be approximated by voltages large enough with respect to the rms output of the noise generator so that there would be negligible probability of missing a count with $M = 0$ and negligible probability of getting a count for $M \geqq M_0$.

A still more complete approach is shown in Figure 4. Here the motion of the missile about one axis is significantly coupled to its motion about another axis, and the target may have a complex form. The coupled two-axis system is simulated on the basic computer, and independent noise sources are used to simulate the different components of the radar noise or other disturbances in the system. The X and Y components of miss distance are then used to drive the X and Y axes of an oscilloscope. The intensity of the oscilloscope trace is controlled by the same pulse which controls the sampling point for the probability distribution analyzer, so that the oscilloscope is blanked out during the entire run except at the point where the range goes through zero. At that point the intensity is brightened and a single spot appears on the oscilloscope for each run—each spot representing the X and Y components of miss on that particular run.

A permanent record of these samples of miss is made with an oscilloscope camera by leaving the shutter open for the few seconds required to take a reasonable sample, say of size 100. An overlay showing the outline of the target to proper scale as viewed from some particular angle can be placed over the photograph of the scope face. Areas can be marked out on the target and different probabilities of kill assigned to each. It is then possible to count the number of hits in each area, multiply them by the proper probability of kill for each area, add the products, and divide by the number of trials to determine the probability of kill of the weapon under those circumstances. This is illustrated in Figure 4.



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Built into Teletype Model 28 page printers is a control device called the Stunt Box. The function of this unique component is to provide extra control facilities for both local and remote operations. Thus—in addition to transmitting, receiving and recording messages and data—the page printer can be used for a variety of switching, remote control and selective calling tasks.

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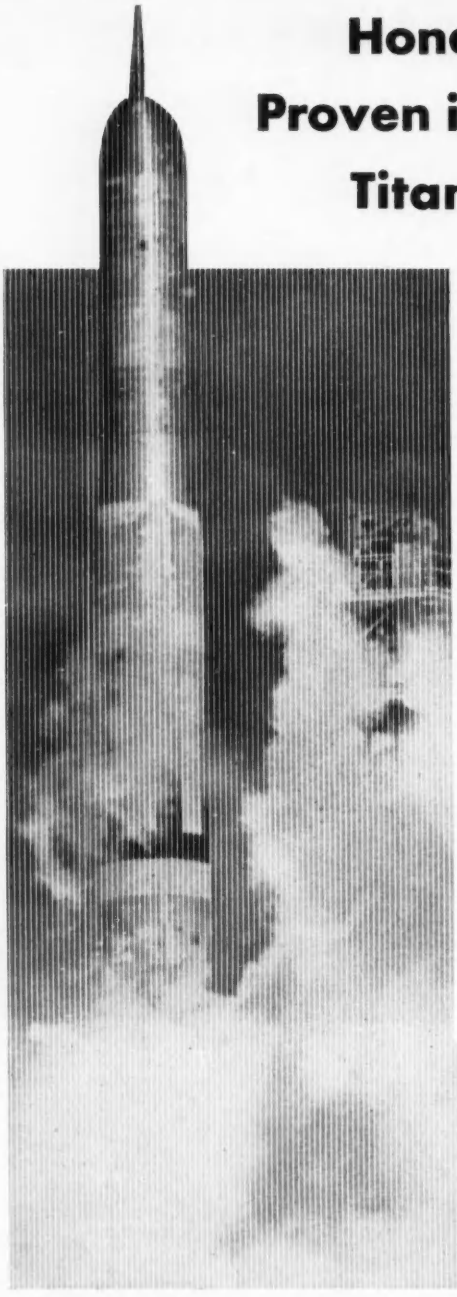

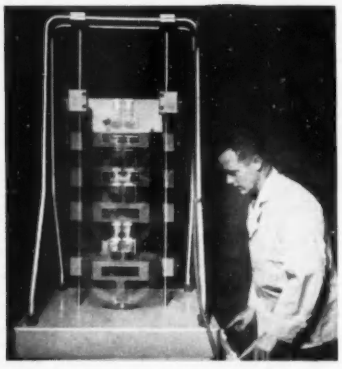

Honeywell accelerometers undergo a saw-tooth shock force of 100 G's for six milliseconds during test at the Environmental Test Laboratory of Avco's Research and Advanced Development Division.

Honeywell Linear Accelerometers, Model 515, were selected by Avco for the flight test instrumentation system of the Air Force TITAN and MINUTEMAN ICBM re-entry vehicles. The Avco Test Program included shock, random vibration, simulated transportation vibration, acoustic noise, standard acceleration, peak longitudinal and lateral acceleration, and high and low temperature tests. "Honeywell's Linear Accelerometers endured our Flight Proof Test Program without structural failure and were given our Flight Proof Test Certification" stated Mr. Paul Myslicki of Avco's Environmental Test Laboratory.

Type LA-500 series Linear Accelerometers are potentiometer output devices that feature constant damping and linear response. These reliable instruments are fluid damped and are designed to operate between −65°F and +175°F. Inherently insensitive to cross coupling accelerations, these non-pendulous instruments are provided with mechanical stops to prevent damage from input accelerations beyond the specified range. Write for Bulletin LA-500 to Minneapolis-Honeywell, Boston Division, Dept. **34,** 40 Life Street, Boston 35, Mass.

Honeywell Linear Accelerometer

Type 500, shown approx. ½ size

- **Full Scale Range:** ±1 to ±60 G
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Electropneumatic Speed Regulator for Turbine Driven Cameras

CLELLAND D. NAIL
GEORGE M. OJA
University of California, Livermore

Turbine driven high speed cameras are being used more and more in recording such phenomena as arc discharges, hydrodynamic shock propagations, and nuclear reactions. The scientific photography group of the Lawrence Radiation Laboratory has used from eight to 16 such cameras during nuclear test operations. Small multifaced mirrors are commonly driven at speeds up to 10,000 rps, and rotor speeds on the order of 30,000 rps are probable in the near future. Variations in optical design permit either framing or smear displays. Typical writing rates are presently on the order of several centimeters per microsecond. Camera running time is a minute or two at most, because violent self-destruction of the mirror is a definite hazard at such high speeds.

Helium gas is directed at turbine rotors at both ends of the mirror, and each camera can use helium at the rate of about 100 cu ft per min—a phenomenal expenditure of the valuable gas. Mirror speed is directly related to the pressure of the gas admitted to the turbine; this pressure is generally controlled by a manually adjusted diaphragm-type pressure regulator valve. Speed-time calibration runs must be made to determine preset pressures if the cameras have to be operated remotely, and the adjustments must be checked several times before the operator can be reasonably certain that the correct speeds will be reached during the test recording. Manual calibration and operation like this usually give speed uncertainties greater than 10 percent.

To increase the timing accuracy of the recording and reduce the helium and the man hours required to set up a camera, a feedback control system was designed to automatically vary the helium pressure directed at the turbines. This system can control mirror speed variations to better than 0.1 percent during a test recording, and duplicates a speed setting with-

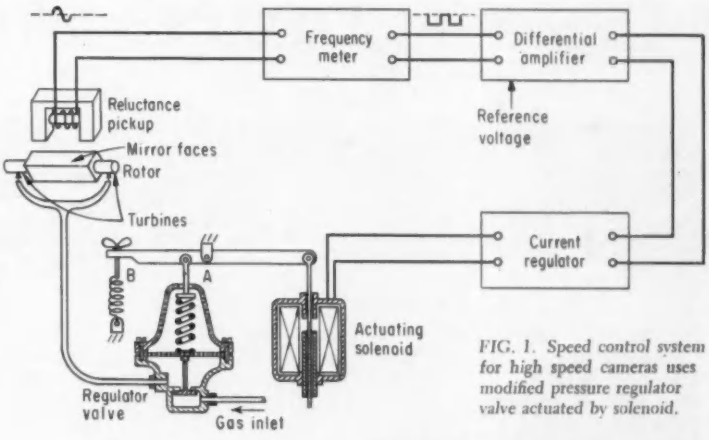

FIG. 1. Speed control system for high speed cameras uses modified pressure regulator valve actuated by solenoid.

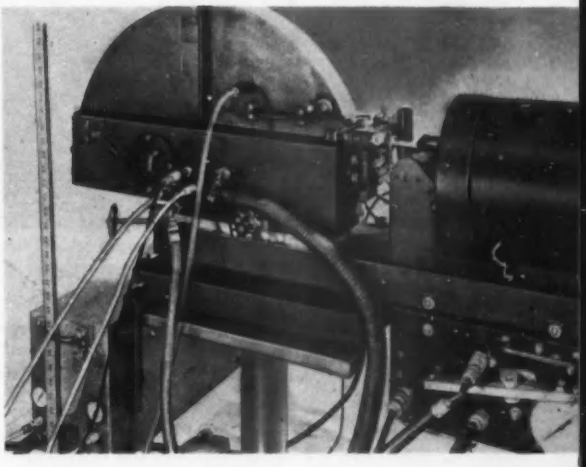

FIG. 2. Typical high speed camera setup with pressure regulator at lower right.

FIG. 3. Close-up of pressure regulating lever arm. Plunger with adjusting screw just to right of pivot bearing at center acts on compression spring in pressure regulator valve.

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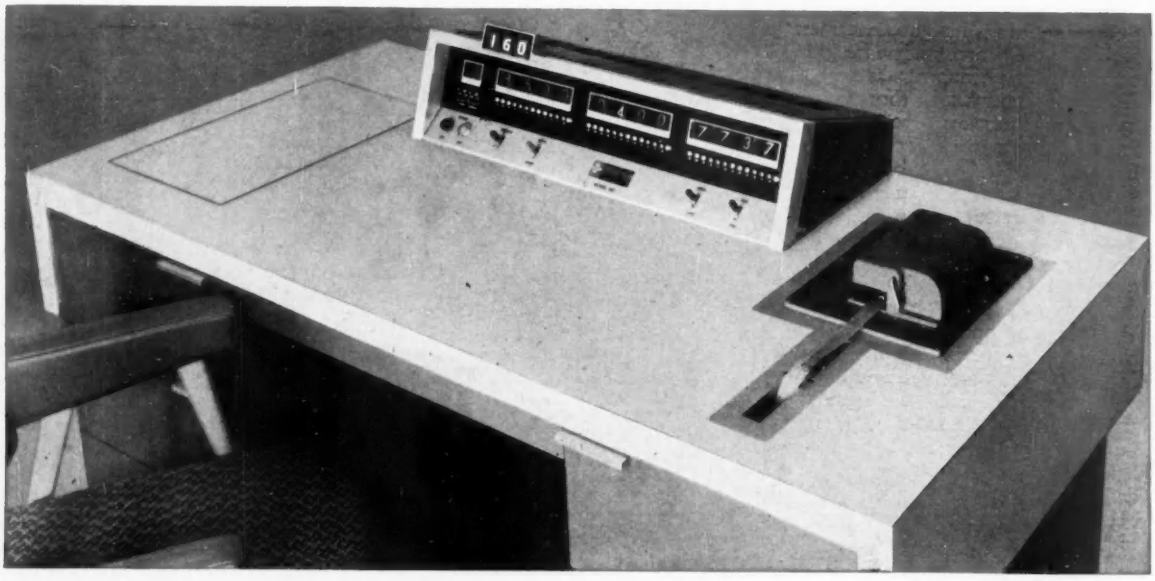

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4. INPUT-OUTPUT: Versatile instructions provided to handle available line of input-output devices: 350 character/second paper tape reader, 60 character/second paper tape punch, electric typewriter, up to 8 magnetic tape handlers (either 15KC or 30KC), card reader, card punch, and line printer.

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in 0.2 percent for long periods.

The control system

The speed of the rotating mirror must be accurately known at the instant an event is photographed, so some kind of transducer is always used to produce a signal proportional to mirror speed. The transducer used is a variable reluctance pickup which produces a pulse output frequency proportional to the rotor speed.

The pulse output from the reluctance pickup is used as the feedback signal for the closed-loop control system shown in Figure 1. The feedback is applied to the input of a frequency meter, which consists essentially of an input amplifier, a Schmitt trigger, and a monostable multivibrator with shaped output. The pulse output of the frequency meter is filtered to obtain a proportional dc voltage and then compared with a reference voltage in a dc differential amplifier. The difference is amplified and applied with the proper polarity to the grid of a current regulator tube. A specially modified regulator valve of the same type previously used to adjust the helium pressure manually is controlled by a solenoid actuated by the current regulator.

A pressure regulator valve is normally adjusted by turning a screw which bears against the top of a compression spring, which in turn transmits the force to a diaphragm. The exit gas pressure acts on the opposite side of this diaphragm to balance the spring force and control the opening of the valve. For use in the feedback system, the manual adjustment screw was replaced by a plunger that is actuated by the solenoid, Figure 1.

The solenoid pushes on a lever arm pivoted at A. The tension of spring *B* is adjusted to give an initial pressure setting substantially below the controlling gas pressure required. This bias pressure allows the solenoid to be operated near its optimum point by reducing the force it must exert. The original compression spring was replaced with one having a much higher spring constant, and the spring deflection was correspondingly decreased. The regulator is actually a two-stage type, so the control diaphragm movement is very small. This, together with the stiffer spring, makes the required solenoid movement less than $\frac{1}{4}$ in. from no current to controlling current even though a mechanical advantage of seven is utilized. (Replacement of the compression spring with a solid link was tried, but this caused the regulator to oscillate.)

Figure 2 shows a typical camera setup with the speed control unit at the lower right. Figure 3 shows some details of the lever arm, which uses ball bearings at all points of applied force. The thumb screw for adjustment of the preset pressure spring is shown at the right end of the arm opposite the solenoid shaft. An adjustable cap screw is used as a stop to limit the maximum travel of the lever arm and thus limit the maximum pressure available at full solenoid current during rotor acceleration.

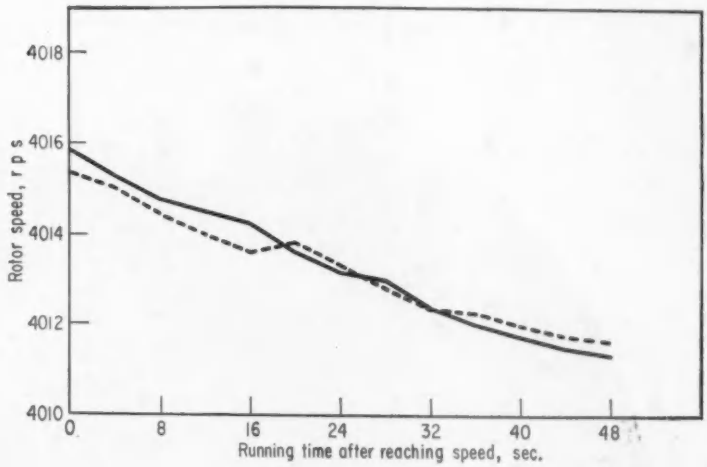

FIG. 4. Results of two successive controlled speed runs.

Initial setup and performance

In the initial setup of the speed control unit, the approximate running pressure must be known for best results. It can be determined quickly by manually operating the lever arm and noting the gas pressure when the desired speed is reached. The rest of the adjustment does not require running the rotor. The bias or preset pressure spring is adjusted to give an output pressure about 15 psi below the determined operating pressure with the lever arm properly aligned. A signal of proper frequency is then applied to the frequency meter, and the reference voltage is adjusted to give half the rated solenoid current. At this value of solenoid current the solenoid air gap is adjusted until the gage indicates the correct pressure for the desired speed. The solenoid operating point is then well below the unstable portion of the force vs distance curve where the slope becomes very great due to a small air gap. This adjustment gives high initial pressure for fast acceleration to the desired speed. The system has a fail-safe feature since the pressure is limited to the bias pressure if the electrical signal fails and will not overspeed.

In tests performed on the experimental model of the speed control unit, some hysteresis was observed during its operation. The effect was attributed mainly to stiction in the solenoid and was practically eliminated by introducing a small 60-cps signal at the servoamplifier to cause "dither".

Figure 4 shows the results of two successive 1-min tests made at 4,000 rps. No attempt was made to adjust the controlling speed to exactly 4,000 rps: although a signal generator and a frequency counter were used, the operating pressure required was only roughly known. As shown by Figure 4, the average camera controlling speed was roughly 0.3 percent high; but the two curves show that the speeds for two successive runs had a maximum difference of less than 1 rps at any one time.

A similar test in which the second test run was made on the following day showed that the average difference in running speeds over more than 2 min of controlled running time was only 0.2 percent. The rotor speed variation over the full running time was less than 0.1 percent. This time is much longer than usual camera runs.

Most of the error in the long term speed duplication is due to changes in the stabilized output voltage of the frequency meter. Other factors are:

- Variations in the ac voltage cause changes in the unregulated plate supply voltage of the amplifier and shift its operating point.
- Solenoid heating causes increased solenoid resistance which in turn requires a higher voltage to produce the same solenoid current and thus maintain the same output pressure as when the solenoid is cold.

The closed-loop servosystem acts to correct all of these factors, producing far better accuracy of speed control than manual methods, with a considerable saving of helium both in adjusting and rechecking the cameras.

Tubexperience in action

Brown Instruments, Industrial Division of Minneapolis-Honeywell Regulator Company, a leading manufacturer of indicating, recording and controlling instruments, recognizes the advantages of long lengths of capillary tubing.

Up to 3000 ft. of capillary tubing in 1 piece

Seldom does an instrument installation require 3000 ft. of capillary tubing in one piece—the quantity is normally much less. But the advantages of long lengths are numerous. A simple long length of capillary tubing has greater ID uniformity than a series of short lengths separately produced. This permits more accurate transmission of data between instruments controlling a process. Instrument manufacturers find that long lengths reduce scrap. They also lessen the number of setups required and the costs of inserting the capillary tubing in flexible metallic protective sheathing.

Superior has spent years in the development of manufacturing processes and quality control procedures for the production of close tolerance tubing. ODs range up to $\frac{3}{16}$ in., IDs from .004 through .040 in. Analyses include Types 304, 316, 321, 347 and 446 stainless; also Monel, Inconel, nickel and carbon steel alloys. Data Memorandum No. 11 gives complete details—let us send you a copy. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

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Simple Go/No-Go Electronic Circuit Checker Pays Off

GEORGE G. ROBINSON
ITI Electronics, Inc.

The automatic tester shown in Figure 1 was designed to check any one of 10 mechanically similar but electrically different electronic panel assemblies for Otis Elevator Co. controls. Sixteen individual go/no-go checks can be performed on each panel. Rate of 1 sec per test has reduced panel testing time by an average of 92 percent when operated by personnel with no technical training. Components checked include resistors between 330 ohms and 1.5 megohms, capacitors, and silicon diodes. Wiring is checked for continuity and a 1,500-volt, 60 cps high-potential test is applied between isolated circuits.

Each panel is checked point-to-point for proper assembly. Incorrect values, out-of-tolerance components, and improperly oriented diodes show up as failures. Each test is accomplished by comparing the item between the points selected with a "standard" in a differential amplifier. The differential amplifier acts as a go/no-go gage and trips a sensitive relay in its plate circuit if the test does not match the standard. Correct test circuits and standards for each test are established by high reliability telephone-type relays. Sequencing between tests is by a stepping switch.

Operation is Simple

Two receptacles with spring loaded contacts are provided to accommodate mechanical variations in the panels. The receptacles are constructed so that the operator cannot attach a panel incorrectly, and end clips secure the panel to the spring contacts. Operating controls consist of the test program selector switch (a program for each of the 10 panels) and a start button. The largest number of tests required on any panel was 16, hence the 16 test lamps. On pressing the start button, testing proceeds automatically at the rate of about 1 sec per test unless a failure occurs. A failure stops the testing and a flashing red "failure" lamp calls the operator's attention to the lighted test number where failure has occurred. After recording the failure the operator resumes testing by pressing the "start" button again.

Figure 2 is a block diagram of the complete system with a schematic of the differential amplifier. Block 1 has 20 contacts, two of which are selected by relays 6 and the program selector 2 as having a component to be tested. The component is connected to the differential amplifier 7 in position 7B, and at the same time a "standard" component of the same type and value is selected and placed in position 7A. The sensitivity of the plate relay 7C is selected for the tolerance desired. A short time after the above connections have been made (to preclude false decisions from switching transients), plate relay 8 is connected and makes the conformity decision.

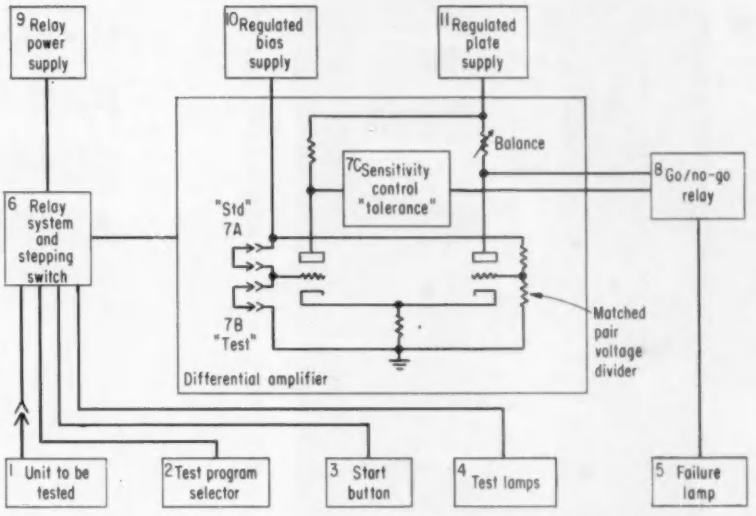


FIG. 2 Heart of the tester is differential amplifier. Relays and stepping switch select component to be tested and standard which it must match, and they set sensitivity of plate relay in differential amplifier to determine tolerance.

Any of the standards used may be changed readily without major disassembly. Tolerances may be changed or adjusted as needed.

Power supplies for the differential amplifier are well regulated. Matched resistors for voltage dividers, careful design and balancing of the amplifier, and high precision "standards" contribute to the accuracy of the test.

The block diagram also emphasizes the simplicity of operation. The test program selector is set once for any one type of panel. Insertion of the panel (1) and starting (3) are hand operations. The test lamps need watching only. If no failure is present, the panel is removed and another one tested. If a failure is present, the operator records it. Test panels with set failure patterns are used to check the functioning of the unit at periodic intervals.

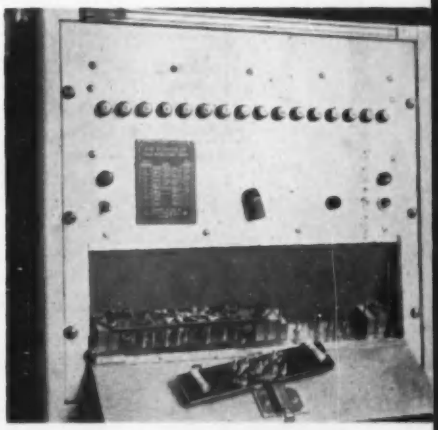
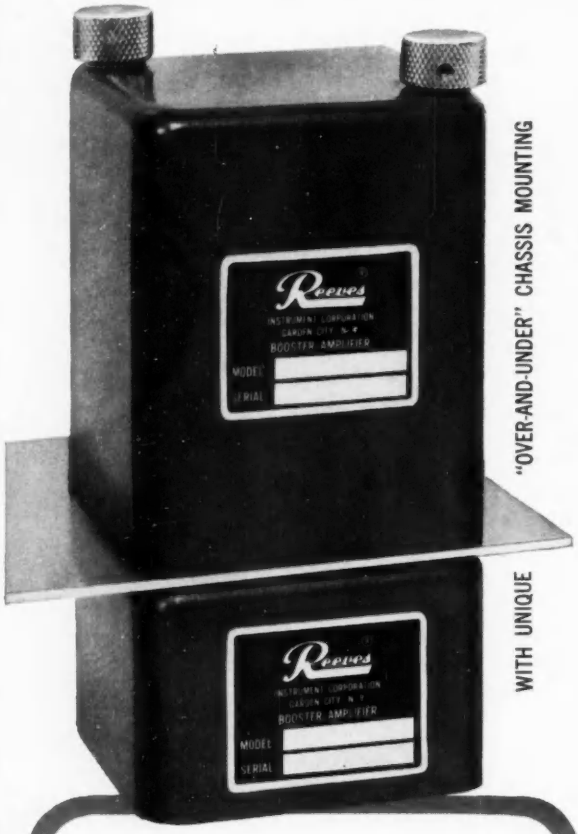
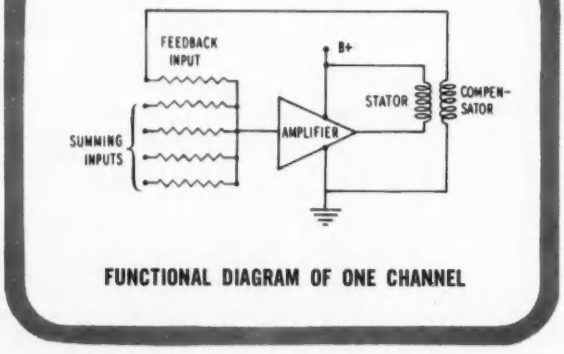


FIG. 1. Programmed tester for electronic panels from elevator control system can make up to 16 tests on each of 10 different panels.

The basic device is adaptable to any comparable electric or electronic assembly. In fact, any parameter which may be converted to a voltage by a suitable transducer may be checked or monitored by this design. Remote monitoring of pressure, temperature, radiation, and the like are logical.





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2. Input Impedance	50 K to 5 Megohms (depending on transfer ratio)
3. Maximum Output Voltage	26V R.M.S.
4. Power Requirements (both channels)	45 V.D.C. @ 16 MA
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6. Voltage Transfer Ratio (amplifier input to resolver rotor output)	0.1 to 10 (as required) accuracy: ±.05% @ 25°C ±0.1% over operating temperature range

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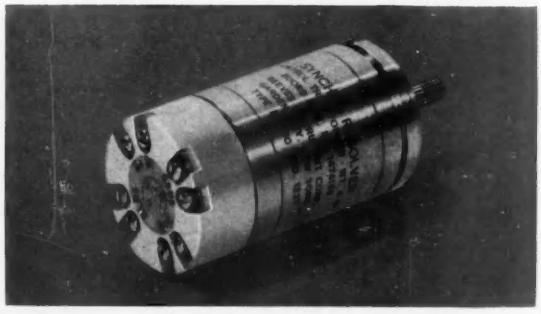

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6RV60

Precision Differential Capacitors for Analog Multiplication

W. F. HAY, Contraves AG.
Zurich, Switzerland

Precision differential capacitors can be used in place of wirewound potentiometers in servo driven multipliers to remove the resolution limitation and contact wear associated with these multiplier systems. In different circuit configurations the capacitor is equally able to do four-quadrant multiplication, division, power raising, or function generation.

The capacitor is made in double units with two independent stator assemblies and two rotors mounted on a common shaft, Figure 1. Each stator assembly is split, and various shaped rotors produce linear, sine, cosine, tangential, or quadratic capacity vs rotation curves. Specially aged aluminum alloy is used to keep linearity errors less than plus or minus 0.2 percent. These errors can be reduced in certain models to less than plus or minus 0.05 percent.

For multiplication, see Figure 2, the two split-stator plates are energized from a 400-cps supply, 180 deg out of phase with the multiplicand input voltage. The multiplier is represented by the rotor angular position. Capacity between the rotor and stator plates is C_r and $(C_o - C_r)$ where C_o is the total capacity of the computing capacitor (between 100 and 200 pf). An amplifier provides the multiplied output $y = x \times f(r)$, where

$$f(r) = \left(2\frac{C_r}{C_o} - 1\right)$$

By designing the rotor so that $f(r)$ is linear, multiplication to the accuracy of the capacitor is possible.

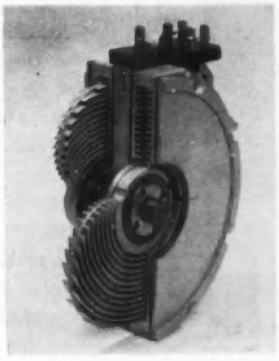
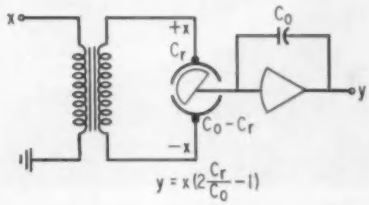


FIG. 1. Cast aluminum alloy function capacitors have split stator, shown here with one half removed.

FIG. 2. Multiplier circuit used with split-stator capacitor.



Pneumatic Analog for Process Control Studies at Yale

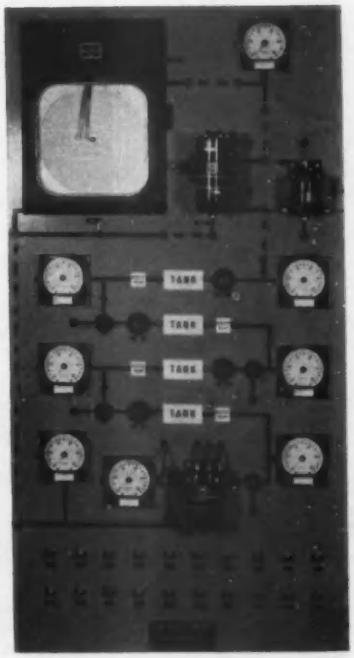
Yale University's Chemical Engineering School recently acquired this pneumatic analog for studying instrument and process behavior. The analog, built by the Bristol Co., includes the effects of load upsets, controlled set-point changes, transmission lines, friction in valves, and nonlinear transmitter characteristics. It can simulate a plant process for the evaluation of various possible control systems.

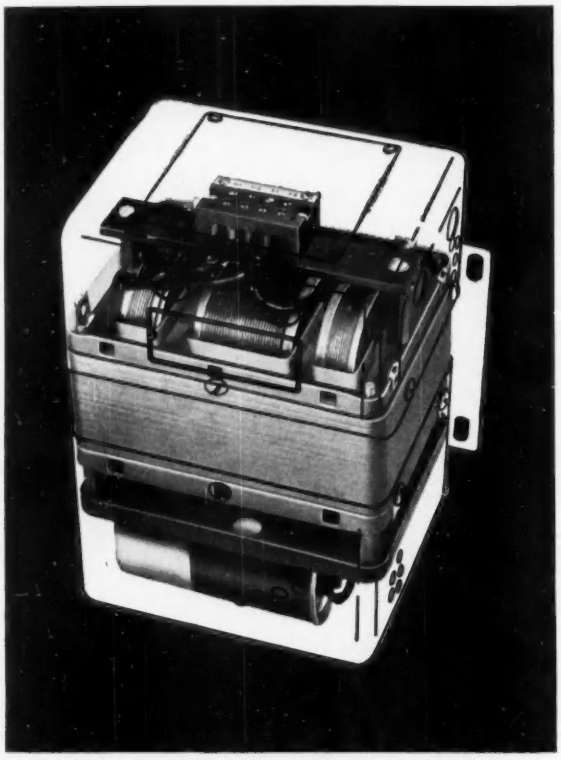
The pneumatic analog consists of a control section, a process section, and a patchboard for programming. The control section includes a two-pen recorder, a pneumatic indicating receiver, a pneumatic controller (proportional plus reset), and a separate derivative unit. The process section consists of four resistance valves, four booster relays, four three-way valves, four capacity tanks, a controller (proportional), a receiver with regulator, and six indicators.

In addition to its simplicity and flexibility, the analog provides accurate, reproducible simulation of the two major process parameters: time constants and gain. Dead time can be introduced easily. Each of the four time constants is simulated by an adjustable resistance valve in series with a capacity tank. Time constant values range from 9 sec to 900 sec in 10 equal steps. Each time constant unit is preceded and followed by a three-way valve for flexibility. The gain change unit is a proportional controller, with the set-point supplied by a pressure regulator.

Twenty quick-disconnects are provided in the patchboard at the bottom for programming a variety of pneumatic circuits. In addition, components in the process section can be used for generating functions for integration and differentiation. Multiplication, addition, and subtraction can be done with a supplementary relay.

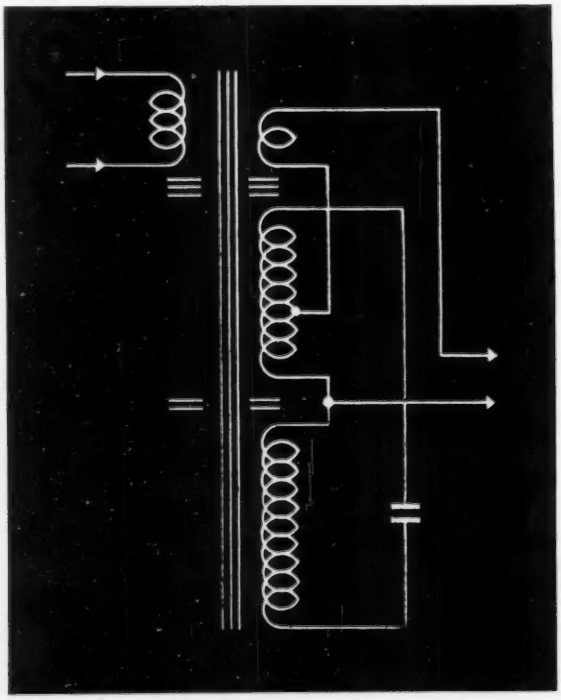
The pneumatic analog is ideal for determining if a proposed control scheme is practical and the probable quality of control. Its greater simplicity and lower cost often make it preferable to an electronic unit.





Phantom view shows simplicity of Sola design. Note absence of components requiring maintenance such as motors, gears, contactors, tubes and relays.

Schematic diagram indicates the complete reliance on static elements. This is the circuit of a representative Type CVS regulator which delivers output having less than 3% total rms harmonic content.



What's missing in this Sola voltage regulator?

When they designed the Sola Constant Voltage Transformer, what did they leave out? Trouble, for one thing. Original equipment manufacturers and plant engineers know that when you build in simplicity, you build out maintenance headaches.

The two illustrations at the left show clearly the Sola's few parts and straightforward design. This compact simplicity is possible because Sola regulators employ static-magnetic methods of voltage control.

The basic Sola design eliminates moving parts, renewable parts, manual adjustments, routine maintenance, and spare parts stock. Because there is nothing to wear out, no tubes to burn out — you know that when you specify Sola voltage stabilization, you automatically specify trouble-free reliability.

Despite this simplification, the Sola gives you these performance benefits: ±1% regulation over input voltage variations as great as ±15%, response time of 1.5 cycles or less, protection against short circuits for itself and its load, a high degree of isolation between input and output circuits, and negligible external field. Type CVS (illustrated with typical circuit diagram) delivers a commercial sine wave with less than 3% total rms harmonic content.

Sola static-magnetic units are available for regulation of common line voltages, as well as filament, plate-filament, computer-circuit and variable voltage outputs. They can also be supplied in step-up and step-down ratios to replace conventional non-regulating transformers.

Whether you are developing new electric or electronic equipment, or have a specific voltage regulation problem, your nearest Sola sales engineer will be happy to discuss your requirements with you.

Write for Bulletin 26F-CV

SOLA

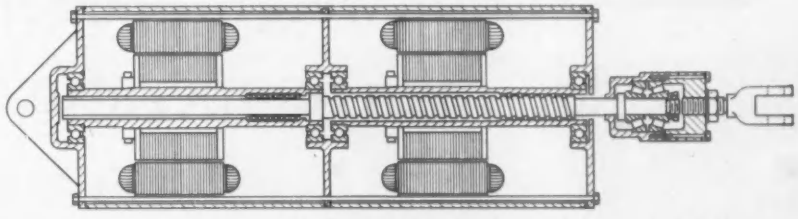
B P C

A Division of Basic Products Corporation

SOLA ELECTRIC CO.
4633 West 16th Street Chicago 50, Illinois

Unique Electric Thruster Uses Two Motors

DALE L. SCHRADER
Southwest Potash Corp.
Now with H. E. Bovay, Jr.



Center shaft through two independent hollow-shaft motors is driven to right or left by difference in speed between motors.

The electric motor device illustrated may be able to supply the high force, high response, linear motion needed to operate conventional process flow control valves and so would be useful in all-electric instrumentation systems, as well as in small plants where pneumatic power is expensive or for operating remote control valves.

In this patented* actuator two variable speed electric motors with separate hollow center shafts are mounted on the same axis. A third shaft is mounted in these two hollow motor shafts by supporting one shaft with screw threads and the other with a spline. If the center shaft is rotated with respect to the motor shaft having the threads, it will move laterally to the right or left, depending on the direction of rotation. The motor with the spline equipped hollow shaft will rotate with the center shaft, which can displace through it either to the right or left. The rotating center shaft must be connected to the device to be actuated, which cannot rotate, with an antifriction bearing.

If the two electric motors operate at identical speeds, the center shaft rotates at this same speed but without lateral movement. If one motor speed is changed with respect to the other, the center shaft will move to the right or left as the screw threads in the motor shaft displace those on the center shaft. The thrusting or pulling force developed is a function of the difference in the torques of the two motors at each respective speed. This difference in torque might be better described as the resistance of the slower speed motor to being driven at the speed of the faster motor.

Although torque characteristics for various types of motors differ, it can be stated generally that when one of these two motors is operating at a given speed, say 1,750 rpm, it will drive the other motor at approximately that speed even though the second motor might be designed to run at a slower speed, say 1,700 or even 1,150 rpm. The slower speed motor thereby operates as a generator, and its resistance, or reverse torque, opposes that of the high speed motor. This situation is understood below when referring to the differential torque of the two motors or to the amount of thrust developed being a function of the difference in the torques.

Many variations in motor types may be used with this device. For example, the left-hand motor could be a synchronous motor and the right-hand motor a variable speed universal or dc motor. Or both motors could be two-speed, single- or three-phase induction motors.

Assume the left-hand motor to have normal full load speeds of 1,725 and 1,150 rpm and the right-hand motor to have normal full load speeds of 1,750 and 1,125 rpm. With control circuits arranged so that the left motor would run at 1,725 rpm while the other was running at 1,125 rpm, a large differential torque would result to move the center shaft to the left. As the displacement limits are approached, the speed of one motor must be changed to approach the speed of the other motor. This is necessary because the two motors are mechanically locked together when the screw threads have been displaced fully in either direction. In this case the left motor must change to its 1,150 rpm speed, which approaches the 1,125 rpm speed of the right motor just before the left lateral limit is reached. At these two speeds the left motor would drive the right motor with allowable slippage, maintaining sufficient lateral force to hold the center shaft at the extreme left.

Two variable speed ac or dc motors could be used with wide variations in speed to control the lateral speed of the thruster. Rotation of the thrusting shaft could also be utilized in combination with the thrusting motion.

The speed of the thrusting shaft to the right or left depends upon the difference in speeds of the two motors and the number of threads displaced. Assume that a speed difference of 120 rpm exists and the screw has 4 threads per in. Each revolution difference displaces one thread, or 0.250 in., providing movement at the rate of 0.5 in. per second. Had there been 8 threads per in., movement would be at the rate of 0.250 in. per sec. However, assume that the speed difference is only 30 rpm or 0.5 rps, with 8 threads per in. This gives linear movement at the rate of 0.0625 in. per sec. If 8 in. of travel are required, a large speed differential may be needed. Assume one motor speed is 1,750 and the other is 1,150, giving a speed differential of 600 rpm or 10 rps. Using a center shaft with 2 threads per in. requires 16 revolutions to displace the thruster the 8 in. At this rate the complete cycle is approximately 1.6 sec.

The thrust force that such an arrangement develops depends on the friction in the screw threads used and the friction in the spline. With an acme thread the formula $2\pi RF = Wp$ can be applied where R is the radius of motor rotor, F is the force developed, W is the force in the thruster, and p is the lead of the thread. If the difference in torque between the two motors is 25 lb-in. and the pitch of the screw is 0.25 in., a force of 628 lbs., neglecting friction, can be developed. However, acme threads will normally have an efficiency of about 30 percent, thereby reducing this to 188 lbs.

If a ball bearing spline and ball bearing screw are used as shown in the illustration, an efficiency of over 90 percent can be obtained. Using the same assumptions as above, W becomes 565 lb. The 25 lb-in. of torque used is equivalent to the full load torque of a 1,200-rpm, ½-hp motor.

* *Licensed to Leslie Co.*

On the new J85 Jet Engine: Lightweight, dependable Kidde high-temperature actuators!

In order to move the variable exit nozzle on the afterburner of the J85 engine, G.E. uses three lightweight Kidde ball screw actuators, similar to the unit shown above. Each actuator employs a ball screw mechanism that weighs only 0.6 pounds and has a shaft diameter of ½ inch.

The Kidde ball screw actuator shown can carry loads up to 1,400 pounds and can operate continuously in a temperature range of from −65° F. to +840° F. At high temperatures, these mechanical ball screws are more reliable than electrical, pneumatic or hydraulic systems. Because they have a minimum amount of back-lash and friction, they can easily perform functions calling for the rapid reversibility of heavy loads. This makes them especially suitable for applications such as thrust reversal, gimbaling rocket or jet engines, atomic scramshaft controls and space flight controls.

Like G.E., you, too, may have a problem which can be solved with Kidde ball screw actuators. For more information on these dependable actuators, write Kidde today.

Kidde Aero-Space Division

Walter Kidde & Company, Inc., 617 Main St., Belleville 9, N. J.

District Sales Engineering Offices: Dallas, Texas • Dayton, Ohio • St. Louis, Mo. • San Diego Calif. • Seattle, Wash. • Van Nuys, Calif. • Washington, D. C.
Walter Kidde-Pacific, Van Nuys, California • Walter Kidde & Company of Canada Ltd., Montreal, Toronto, Vancouver

NEW PRODUCTS

TRANSISTORIZED TAPE SYSTEM carries card system price tag.

Photo at right shows the basic components of the Honeywell 400, a new transistorized data processing system said to be the most powerful in the moderate price class. Designed to sell for less than any comparable magnetic tape system, the new package includes a powerful central processor (back wall), a standard card reader (operated by girl), a high speed printer (foreground), and four tape units (right). Tape units and the 900 line per min printer are the same as those used in the larger Honeywell 800 systems. Transistorized computer will handle up to 6,000 three-address operations per sec and features a 1,024-word core memory. As shown, system will rent for $8,660 per month.—Datamatic Div., Minneapolis-Honeywell Regulator Co., Wellesley Hills, Mass.

Circle No. 309 on reply card.

TORQUE TESTER rides on air.

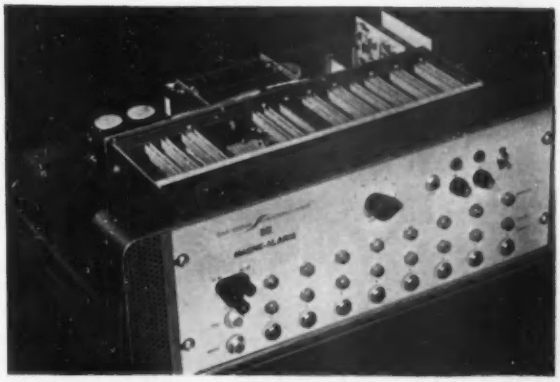
Pictured here is the DRC Model 67-M2 Torque Tester, an extremely precise instrument for measuring torque levels far below the range of more conventional torque test equipment. Using an air bearing suspension system developed at MIT's Instrumentation Lab, the device features accuracy to within 0.1 percent. It measures by summing torques about its air-supported shaft. Microsyn elements provide both angle readout and torque restraint. Primary windings of the torquer and a Weston product resolver are excited in series by an ac source. Their secondary windings receive the current fed back to the torque generator; this provides a measure of the torque required to null the shaft. A paddlewheel immersed in oil damps the feedback restraint loop. Suggested applications include performance tests of ball bearings, gyro motors, meter movements, dampers, etc.—Dynamic Research Corp., Stoneham, Mass.

Circle No. 310 on reply card.

NEW SCANNER hits 20,000 points per sec.

Capable of handling both millivolt and higher level signals, this new solid state alarm scanner will scan up to 20,000 points per sec. Unit provides adjustments for both bogey value and tolerance on each input. Visual and audible alarms are available as well as alarm point identification and memory. Called the Magne-Alarm, it accepts thermocouple and strain gage inputs, external voltages, or resistances and provides a minimum of 130-db common mode rejection at 60 cps. Input for each point consists of a winding on a magamp and is isolated from other circuits within the alarm unit and from other inputs.—San Diego Scientific Corp., San Diego, Calif.

Circle No. 311 on reply card.



CONVERTS A DC CONTROL SIGNAL TO A PROPORTIONAL VALVE-ACTUATING AIR PRESSURE

and prevents pneumatic freeze-ups with an integral heater

The Swartwout Type P2R Power Relay is a simple null-balance device. By balancing a magnetic force against the air-loading pressure, it maintains an accurate linearity between electrical input and pneumatic output. It has no vacuum tubes, journal bearings or other friction surfaces. There is a high-capacity booster relay in the pneumatic section to make valve actuation extremely fast. And, if you want, a heater can be included to prevent cold, moist air from freezing the pneumatic block.

You have only one field adjustment to make on the Power Relay: Zero. The range (1—5 milliamperes DC input; 3—15 psi output) is permanently adjusted at the factory. And the unit is temperature compensated for accurate calibration over a wide ambient range. If desirable, you can change the Power Relay from direct to reverse action.

One customer chose the Power Relay because of its superior sensitivity, linearity and reproducibility. Another uses the heater model on a cryogenic-fluid application.

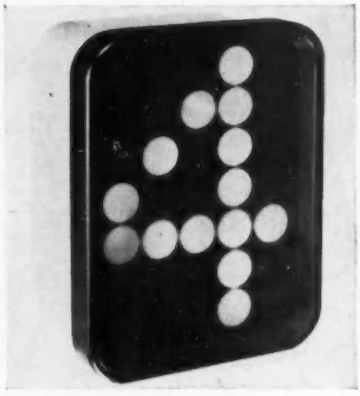
You'll probably have your own good reasons after reading Bulletin A710-B. *Write the Swartwout Division, Crane Co., Hooksett Industrial Park, Manchester, New Hampshire.*

SWARTWOUT DIVISION CRANE CO

. . . world leader in electronic process instrumentation

NEW PRODUCTS

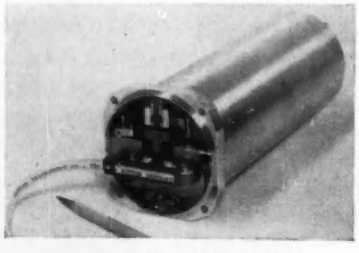
DATA HANDLING & DISPLAY



GIANT INDICATOR

A new series of counting indicators offers giant size illuminated characters, 4½ in. high. Accepting input pulses, it will register the decimal count, generate an output pulse to 10 to drive the next indicator. No bulbs can burn out since high light levels are produced by neon tubes and optics; numbers are readily observed from over 100 ft and at angles up to 70 deg. The counters and decoders use semiconductor techniques, requiring low power (2½ watts). Six models are available accepting a variety of inputs from rates up to 1 Mc to four-line binary coded decimal.—Navigation Computer Corp., Philadelphia, Pa.

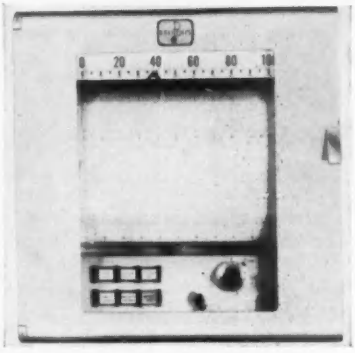
Circle No. 312 on reply card



SMALL BUT PRINTS FAST

Printing speeds of over 30 characters per sec on $\frac{5}{16}$-in. paper tape are possible with a new device only 9¼ in. long. With a self-contained tape supply the printer fits a standard 3-in. instrument case. The speed and size of the instrument make it suitable for computer print-out, among other applications. It was developed for Stromberg-Carlson and is designed to sell for less than $500.—Potter Instrument Co., Plainview, N. Y.

Circle No. 313 on reply card



CHOOSE ANY OR ALL

The Selectomatic Dynamaster recorder allows the user to select any or all of 24 points for recording. Setting of a two-position pin for each point determines the program of variables measured and recorded. For continuous measurement of one point or for calibration checks, the selector switch motor is deenergized and the selector is turned to any desired point. —The Bristol Co., Waterbury, Conn.

Circle No. 314 on reply card

PLUS . . .

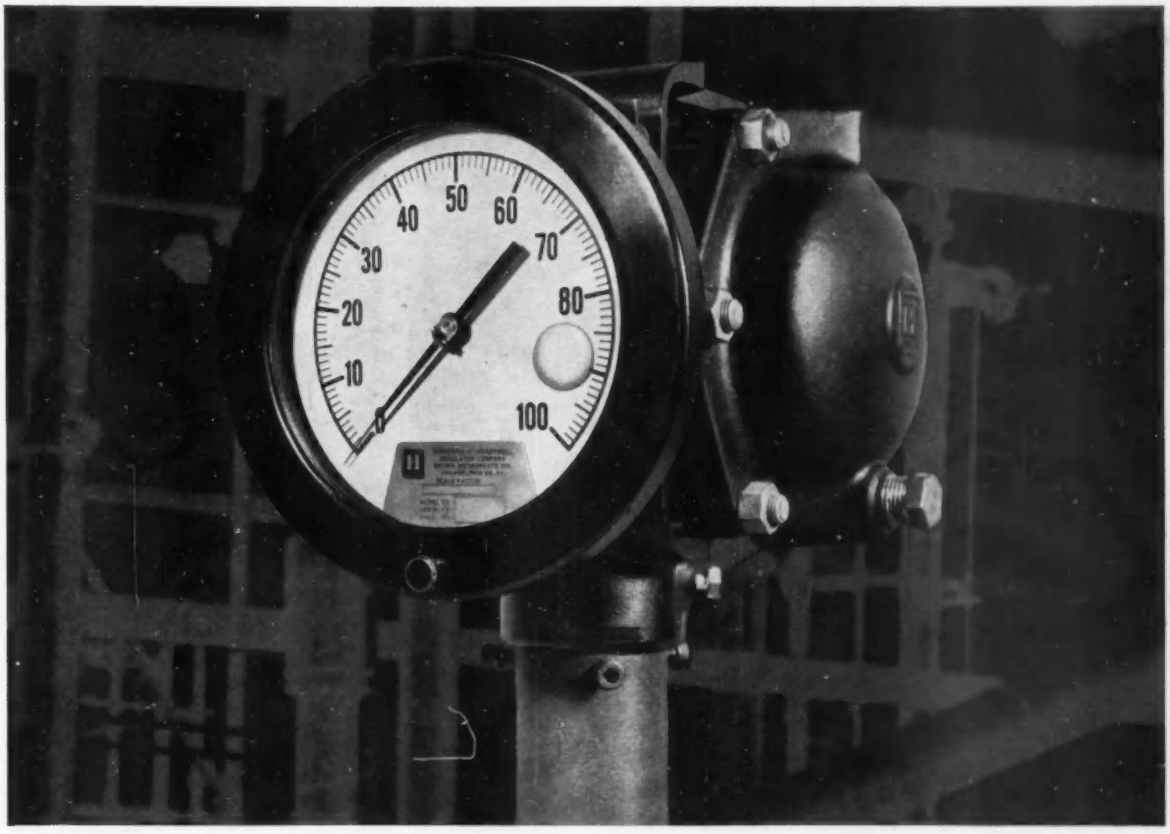
Three new small display tubes recently announced are (315) a 2½-in. **Iatron storage cathode ray tube** claimed to be the smallest, brightest, and lightest of its type from **ITT Laboratories**, Fort Wayne, Ind. . . . (316) The industry's smallest **direct view storage tube** with electrostatic deflection made by **Allen B. Du Mont Laboratories, Inc.**, Clifton, N. J. . . . and . . . (317) a new **scan-conversion tube** for large-screen radar display in brightly lighted rooms which is available from **RCA Electron Tube Div.**, Lancaster, Pa.

Circle No. 315, 316 or 317 on reply card

RESEARCH, TEST & DEVELOPMENT

DIGITAL AT LOW COST

Designed for general laboratory and industrial applications, a new dc digital voltmeter offers an accuracy to within 0.5 percent of full scale with 1/24 sec speed of response at a low



New indicating bellows meter is accurate, rugged and safe in any atmosphere

Use this new bellows meter for any flow or liquid level application where you want local indication, but don't need recording or transmission. It combines the advantages of the mercuryless bellows meter body with the convenience of an easy-to-read 6-inch dial indicator.

Make pressure connections from either the top or bottom of the meter body, depending on whether you want the meter to be self-venting, draining or purging. And forget corrosion worries; all parts of the bellows exposed to process fluids are of seamless stainless steel construction.

This rugged meter will perform accurately in the toughest service. Two meter bodies are available with pressure ratings of 1000 and 2500 psi, tested at 1500 and 4000 psi respectively. And you can use the meter in hazardous atmospheres because it is self-powered . . . at any ambient temperature between –40° and +250°F. In the indicating movement, a stainless steel pointer pinion and a nylon-faced gear sector assure long life and sustained calibration accuracy of ±1% full scale (ranges of 0-50 inches of water and above) and ±1¼% full scale (ranges below 0-50 inches of water).

This new bellows meter has many other features . . . ease of calibration, simple range change, automatic ambient temperature and static pressure compensation, to name a few. Your nearby Honeywell field engineer can give you complete details. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

75th YEAR
PIONEERING THE FUTURE

Honeywell

First in Control
SINCE 1885

CIRCLE 145 ON READER SERVICE CARD 145

NEW

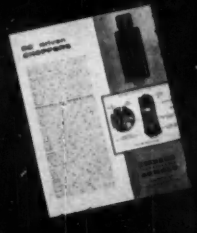
DC driven CHOPPERS

What... No AC?

In transistorized d-c amplifiers, the use of a d-c driven Chopper instead of the usual a-c drive, removes an additional source of stray a-c signals from the critical chassis wiring. The 94 cycle chopping rate also eliminates the null off-sets resulting from the use of a 60 cycle chopping rate.

In portable d-c amplifiers, the advantages of low level operation plus a 94 cycle chopping rate are now available, using a 12, or 24 volt battery as the chopper drive source.

Write for Catalog 554.



STEVENS INCORPORATED ARNOLD

QUALITY SINCE 1943

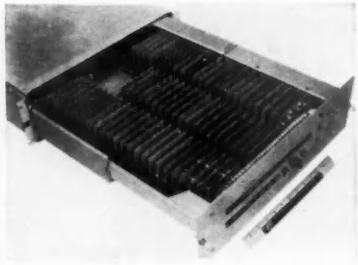
7 ELKINS ST., SOUTH BOSTON 27, MASS.

S/A-20-1/5

NEW PRODUCTS

price: $295. Small in size (6¾ in. high by 4¾ in. wide by 9 in.), the meter also has the advantage of numbers that slide smoothly by the viewing window in the quasidigital mode rather than "frame" as in the digital mode, which is also available. Input impedance is 1 megohm for all ranges, which are 0-2.5, 0-25, and 0-250 volts. Ranges of 0.25 and 0-2500 volts are available at additional cost. – Electro-Logic Corp., Venice, Calif.

Circle No. 318 on reply card



CHECKS CORES

Designed for a standard relay rack, this new solid state magnetic core tester is 5¼ in. high and 20 in. deep. It will check the operation status of a 19-bit, 4,096-address core memory. The test may be on selected addresses and bits or in sequence on all addresses with every combination of the bits. It is possible to start or stop from any address with any word pattern. A 105- to 125-vac, 50/60-cps supply is needed. Price is $10,500.–Packard Bell Computer Corp., Los Angeles, Calif.

Circle No. 319 on reply card

SENSES THERMALLY

This new Model TBA gas analyzer uses a thermal conductivity sensing detector to monitor and indicate carbon dioxide concentrations under 2 percent in nitrogen gas streams. The sensing cell is immersed in a tempera-

BASIC BUILDING BLOCKS FROM KEARFOTT

FREE GYRO

A highly reliable, two-degree-of-freedom instrument utilizing AC synchros at each gimbal axis. Designed to operate under the most severe missile conditions, this gyro has AC torquers mounted at each gimbal axis to permit command positioning or slaving of spin axis to desired reference position; each torquer capable of producing a precession rate of 360°/minute with 12.5 watts/phase power input.

TYPICAL CHARACTERISTICS #Q2315

Environmental Capabilities
Temperature Range.
(operative): — 54°C to +71°C
(non-operative): —65°C to +85°C
Altitude: Unlimited
Vibration: 10g, 10-2000cps

Pickoffs
Excitation:
26V, 400 cps, single phase
Output (sinusoidal):
11.8V ± 5% max.
Error from E.Z.: 10 min. max.

Motor
Excitation:
115V, 400 cps, three phase
Speed: 23,500 RPM
Momentum:
2.25 x 10^6 gm cm^2/sec.

Caging and Preset Provision
(Electrically energized torquer type)
Excitation: 115V max./phase
Torquer Constant:
22.8 dyne cm/$Volt^2$

Performance Characteristics
Free Drift:
0.5°/minute each axis
Runup Time:
1 minute max.
Torquing Rate:
360°/min. (intermittent)
40°/min. (continuous)

Physical Features
Dimensions: 4" dia. x 5¾" long
Weight: 5.5 lbs. (approx.)

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

SIZE 11 SYNCHRONOUS MOTOR

Featuring pull out torque efficiency of 50% nominal with 3.4 watts input and 3 watts pull out power, this synchronous motor represents a major achievement in terms of performance for a unit of this extremely small size. Additional advantages made possible by Kearfott's unique design include resistance to environmental extremes, light weight construction and low unit cost. This motor and its variations are available in production quantities.

TYPICAL CHARACTERISTICS R172

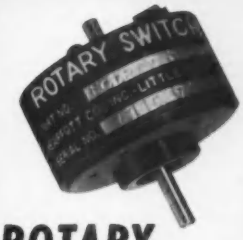
Excitation:	Phase 1	Phase 2
Voltage	40V	40V
Frequency	400 CPS	400 CPS
Power	2.3 Watts	2.3 Watts
Current	0.157 Amps	0.157 Amps

Performance:

Synchronous Speed	8000 RPM
Stall Torque	0.2 In. Oz.
Pull Out Torque	0.35 In. Oz.
Pull In Torque	0.15 In. Oz.

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT



ROTARY SWITCH

Kearfott's rotary switching devices for missile and aircraft systems are used to sequence or switch circuitry as a function of time or shaft position. Used in conjunction with sensitive relays or solid state switching techniques, high current loads can be handled. These switches consist primarily of shaft assembly and bearing mounted cylinder divided into conducting and non-conducting segments with continuous track for common input. Multiple conductor "broom" type brushes ride on each cylinder track while number of tracks and segmentation of each is function of the number of circuits and type of "on-off" sequencing required.

TYPICAL CHARACTERISTICS P1280-11A

Number of switching tracks: 2

Angular Segmentation (both referenced to 0° start):
Track 1 — Non-conducting about 0° + 50°
Track 2—Conducting 0° -180°
Non-conducting 180° -0°

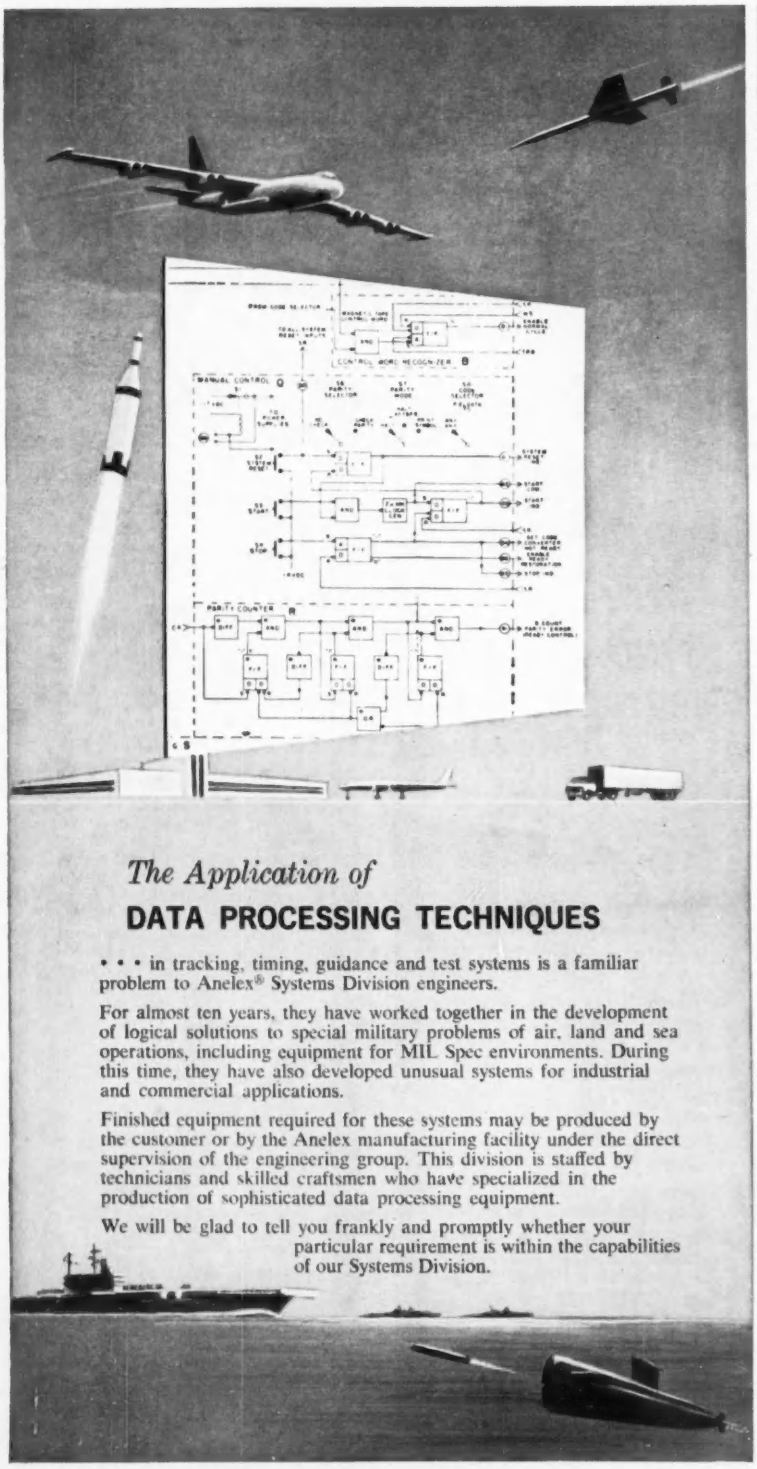
Mechanical Accuracy of Segmentation:
±1° (better as required)

Starting and Running Torque:
0.1 oz.-in.

Current Capacity:
50 ma at 28V/Brush (suitable for any sensitive relay or solid state switching circuits)

Write for complete data.

KEARFOTT DIVISION GP **GENERAL PRECISION, INC.**
Little Falls, New Jersey



The Application of

DATA PROCESSING TECHNIQUES

• • • in tracking, timing, guidance and test systems is a familiar problem to Anelex® Systems Division engineers.

For almost ten years, they have worked together in the development of logical solutions to special military problems of air, land and sea operations, including equipment for MIL Spec environments. During this time, they have also developed unusual systems for industrial and commercial applications.

Finished equipment required for these systems may be produced by the customer or by the Anelex manufacturing facility under the direct supervision of the engineering group. This division is staffed by technicians and skilled craftsmen who have specialized in the production of sophisticated data processing equipment.

We will be glad to tell you frankly and promptly whether your particular requirement is within the capabilities of our Systems Division.

for further information, write or telephone,

ANELEX

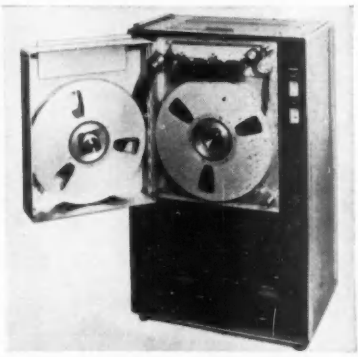
ANELEX CORPORATION

150-D CAUSEWAY ST., BOSTON 14, MASS.

NEW PRODUCTS

ture controlled oil bath, and bridge current is controlled via a transistor regulated power supply. Equipment accuracy is said to be within plus or minus 0.05 percent.–Industrial Instruments Engineering Corp., Cedar Grove, N. J.

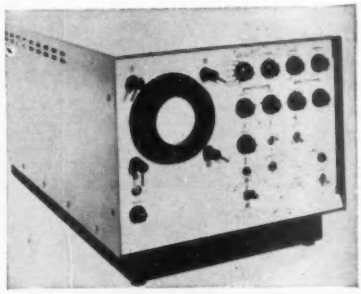
Circle No. 320 on reply card



LIGHTWEIGHT RECORDER

Weighing only 100 lb, the PS 216-D portable digital magnetic tape instrumentation recorder/reproducer measures only 16½ in. wide by 25½ in. high by 14 in. Standard tape speeds from 1⅞ to 60 ips are provided for 1-in. tape using the new PCM 16-track telemetry tape configuration. Also included is a tape magazine for rapid tape replacement or for interchange with a continuous loop magazine. Standard NARTB 10½-in. reels are used.–Precision Instrument Corp., San Carlos, Calif.

Circle No. 321 on reply card

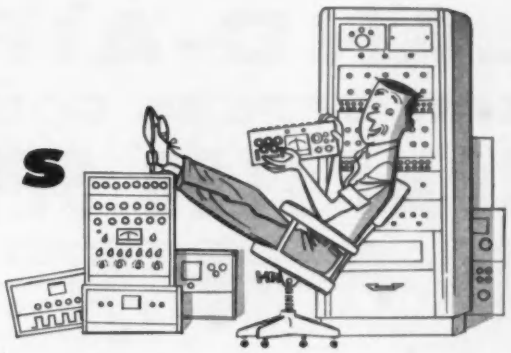


WORLD'S FASTEST

Claimed to be the world's fastest, most advanced oscilloscopes, the Models 707 and 708 Milli-Mike instruments can detect and display phenomena lasting only 20 billionths of a second. The oscilloscopes are traveling wave

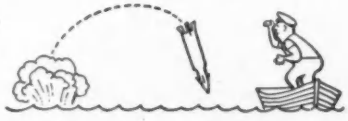
ANALOG COMPUTERS

—How You Can Use Them



It's no secret that people who make analog computers spend a lot of time talking to each other. Pity the chap who's trying to figure out how all this palaver applies to him. He's in a semantic jungle.

First, let's define what kind of computers we're talking about. At Donner, we're concerned with two types—general purpose and fixed purpose. Quickly, general purpose analog computers solve equations describing lumped parameter, dynamic systems expressed in linear or non-linear differential equations, or transformed (La Place) equations. They are used to directly simulate systems described by these equations. They are also used to analyze sections of these systems. In other words, this type of computer gives you freedom and flexibility limited only by your imagination.



THE FIXED PURPOSE COMPUTER

Actually, there's not much difference between general purpose and fixed purpose computers. The point is that fixed purpose computers fit neatly into your system to do a specific job. You don't have to worry about programming—that's built in. All you do is turn the knobs. It may interest you to know that 80 to 90 per cent of analog computing equipment sold is fixed purpose. At Donner, fixed purpose gear is one of our big specialties. It comes in a wide variety of sizes. Typical of lightweight devices is the solid state "think" device developed by Donner for the Polaris missile which monitors flight performance. If, for example, in the initial portion of the flight, the missile does not achieve sufficient velocity by a predetermined time, the Donner system aborts the flight. The missile gets the go-ahead only as programmed.

Another fixed purpose computer is the on-line wind tunnel data reduction computer recently built by Donner for the National Research Council of Canada. This computer receives, processes, and analyzes signals from force transducers mounted on a scale model. Such coefficients as lift and drag are continuously and simultaneously studied.

COMPUTERS FOR ANALYSIS ARE OFTEN USED

Fixed purpose analog computers are used in linear and non-linear programming. Here, they solve problems of gasoline blending, game theory, logistics, military tactics, and operations research.

Other fixed purpose analog computers are used to study spectral density and variation coefficients. The spectral density computer is used to make vibration, noise and system transmissibility studies. Statistical evaluation of non-continuous or discrete process can be performed with variation coefficient computers. In this application, achieved values are put in and average value, standard deviation, and variation coefficient instantly computed out.

COMPUTERS FOR INFORMATION CONTROL, SIGNAL CONDITIONING, AND PROCESSING

Three other examples of fixed purpose analog computers in use are a missile tracking computer, signal conditioning computer, and process control computer.

The missile tracking computer receives distance and angular displacement information from tracking radars. From this information, the computer provides a continuous plot of the missile's position in cartesian coordinates.

Signal conditioning computers modify frequency, phase or amplitude to restore or control signal characteristics. They are used for hybrid computer links, preamplification of low level transducer signals, spectrum segmentation with active filters, or automatic control of dynamic range.

Process control computers receive signals from transducers, linearize the signals, compare them with set points both fixed and variable, and provide control signals with rate, reset, and proportional adjustments.

LET'S HEAR FROM YOU

Enough talk. We've given you a rough idea what Donner has done for other people. Let's find out how this applies to you. Send us a brief description of your problem; a paragraph or two will do. We'll write back telling how Donner can help and send you a Tech Note if it applies. If writing's a chore, our engineering rep will be happy to discuss methods of solving your problem with Donner's computer systems. Just contact us for his name. Either way, you'll get information that applies to your particular problem. Please address Dept. 21.

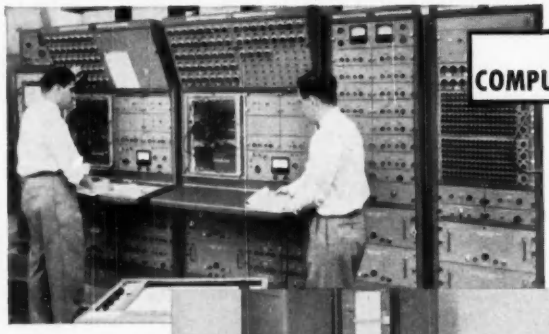
DONNER SCIENTIFIC COMPANY

CONCORD, CALIFORNIA

26

CIRCLE 149 ON READER SERVICE CARD 149

LAND-AIR, INC.
NOW OFFERS COMPLETE
COMPUTER SERVICE



ANALOG COMPUTING EQUIPMENT

for problems having complex equations where several dependent variables are involved. This method offers speed and flexibility as it performs all of its operations simultaneously, rather than in sequence.

DIGITAL COMPUTING EQUIPMENT

with unusual flexibility of programming schemes. Ideally suited to both repetitive and non-repetitive problems, regardless of complexity.

Take advantage of this experienced, versatile engineering staff to solve your engineering, research, manufacturing or production problems

Computer Center service is offered in three ways for your convenience: 1) Computer Center personnel to perform the entire analysis, programming, and solution of a given problem; 2) the client, when qualified, performs the analyses and programming, and operates the computer with staff personnel assisting as necessary; 3) center and client personnel form a team to work together in computer programming, operation and analysis of the results of the problem.

Land-Air, Inc. has computer programming and operation experience dating back to 1949, at which time the monitoring and measuring of missile performance at Pt. Mugu, California was contracted to Land-Air. Since that time, our staff engineers have participated in the solution of a wide variety of problems in many different types of industry. This experience is available to clients who do not have computing equipment available, who wish to gain experience with computing equipment, or who require additional personnel or computer time to supplement their own facilities. In all cases, it is the objective of the Land-Air Computing Center to apply creative efforts to obtain the best solution to problems, with positive results obtained with a minimum of computing and programming time.

- AC and DC Rotating Machine Simulation
- Aircraft and Missile Simulation
- Automotive Engine and Suspension Problems
- Chemical Reactor Simulation
- Control System Dynamics
- Electrical System Analysis
- Flutter and Vibration Studies
- Guidance System Design
- Heat Transfer
- Implicit Synthesis
- Linear and Non-Linear Programming
- Nuclear Reactor Simulation
- Process Control
- Structural Analysis

Land-Air INC.
a subsidiary of California Eastern Aviation, Inc.

For further information and literature, phone UNderhill 7-7550 or write to:

7444 WEST WILSON AVENUE
CHICAGO 31, ILLINOIS

NEW PRODUCTS

deflection-types designed to display both single transient and repetitive phenomena. The 707 has a sensitivity of 55 mv per trace width and a spot size of 0.0002 in. The 708's sensitivity is 5.5 mv per trace width with a 0.0015-in. spot size.—Edgerton, Germeshausen & Grier, Inc., Boston, Mass.

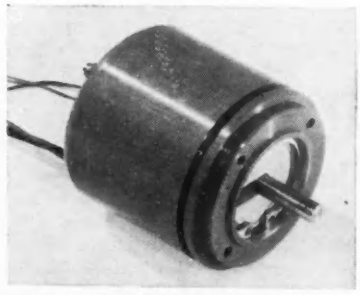
Circle No. 322 on reply card

PLUS . . .

(323) **Ardwin Microlab, Inc.,** Stoneham, Mass., now has a line of laboratory and industrial **counters** using cold cathode counting tubes and a transistorized drive circuit. . . . (324) **A desk top computer** available from **Boonshaft and Fuchs, Inc.,** Hatboro, Pa., gives instantaneous solutions to statistical quality control problems with accuracy to within 2 percent. . . . (325) Sold as part of the Kidder magnetic printing tester kit, the Model 305-U11 **magnetic ink tester** made by **Ballantine Laboratories,** Boonton, N. J., has a go/no-go scale for judging checks imprinted with magnetic ink.

Circle No. 323, 324 or 325 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



PRODUCES TWO OUTPUTS

This two-speed synchro is the newest answer to the problem of increasing the accuracy of shaft position data transmission. Instead of using a gear train, with its inherent problems, the stator of this device has two separate windings. One set produces the normal signal pattern of one cycle of output voltage, while the other puts out 11 cycles, for each rotation. The ac-

Whatever you need a data printer for,
*Clary has a **proven** model to do the job*

At Clary you'll find the world's largest selection of solenoid actuated digital data printers.

These include Parallel Entry Printers, Printing Timers, Time-Data Printers, and Serial Entry Printers. All are reliable, proven printers... printers whose simple circuitry, low cost, small size, desk top mounting, and modern design have made them the most "asked for" printers in the world.

Clary Printers are now being used in the following applications:

Automatic Checkout Systems
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Digital Voltmeter Readout
Logging of Time Signals from Digital Clocks
Shaft Position Readout
Instrumentation Data Recording
Logging of Time and Origin of Alarm Signals
Automatic Engineering Data Recording
By-Product Accumulation of Office Machine Operations
Process Control Data Recording

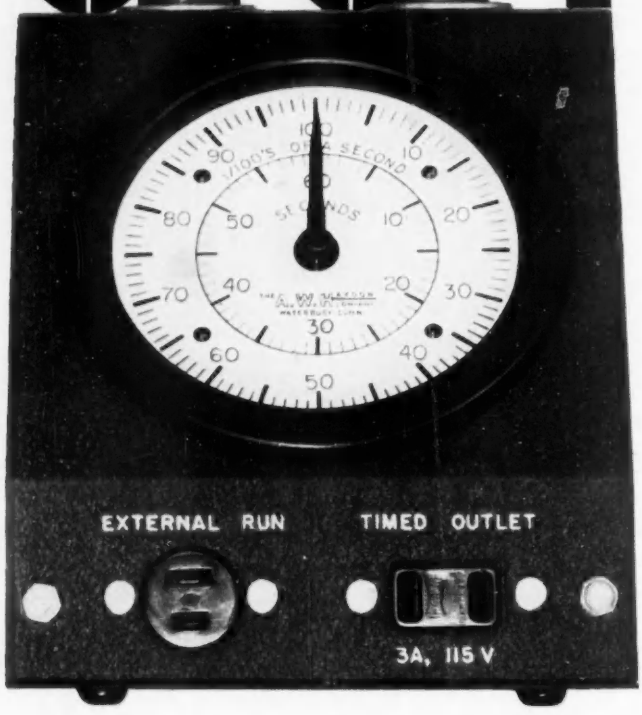
Clary

ELECTRONICS DIVISION
San Gabriel, California

Manufacturer of business machines, electronic data-handling equipment, aircraft and missile components.

CIRCLE 151 ON READER SERVICE CARD

STOP!



Look what happened when A. W. Haydon designed a new LABORATORY STOP CLOCK

You just won't find these features in any other stop clock. This versatile timer-of-all-work was designed by engineers who understand timers and timing...and who needed a precise time reference in their own work. **Timed outlet**—energized whenever clock runs, supplies 115V, 60 CPS, 3 amp to time and control external loads simultaneously...manually or automatically. **External Run Socket**—for remote running, using a control cable... manually or automatically (when wired into a system). **Clutchless timing mechanism**—needs no warm-up, make-ready or pre-start. Synchronous motor starts and drives instantly. No power consumed except during timing and reset. **Independent RUN and RESET** buttons for manual, local control. **Schematic diagram** and control circuitry silk-screened on bottom of housing for ready reference. ■ Bench type precision stop clocks are available with optional remote control for manual or automatic running and/or resetting. Clocks operate on commercial 115V, 60 CPS power; accuracy is ± 25 milliseconds. Low power drain: only 2 watts, timing. Sweep second scale calibrated in 10 millisecond increments; totalizer scale calibrated in seconds, up to 1 min. Sturdy instrument case requires only 4¼" square bench space. For complete specifications, write for Bulletin ET-702. Ask also about panel-mounting versions.

THE A.W. HAYDON COMPANY
246 North Elm Street, Waterbury 20, Connecticut

CIRCLE 152 ON READER SERVICE CARD

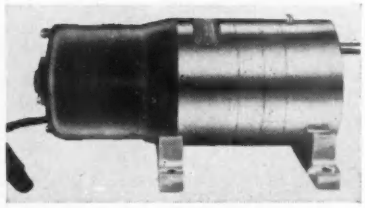
curacy increase is therefore the same as that of an 11 to 1 gear ratio. System error has been shown to be less than 1.4 min with a 350 to 1 signal to null ratio.—Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.

Circle No. 326 on reply card

HALF-OZ SWITCH

The snap action pressure switch shown above is only 1 in. long, has a 1 in. diameter, and weighs just ½ oz. With an operating range of 0-500 psi in air, fuels, lubricants, gases, or other media, it is repeatably accurate to within plus or minus 0.5 percent of original setting, depending on the operating range. Its SPDT switch is rated at 6 amps at 125/250 vac. The Ni Span C capsular-type sensor assures good sensitivity and repeatability and low hysteresis and drift from minus 65 to plus 300 deg. F.—Pamar Electronics Co., Farmingdale, N. Y.

Circle No. 327 on reply card



DETECTS LOW SPEEDS

The Co-Rater centrifugal governor can accurately detect speeds under 100 rpm to as low as ½ rpm using a differential measurement between known input speed and speed being detected.

CUSTOM DIGITAL SYSTEMS

From Process Control to Satellite Orbit Prediction

State of the art digital systems can be designed, built and delivered by Packard Bell Computer in 60 to 180 days. The "building blocks" exist in hardware, ready for custom assembly. Intimate technical knowledge of this proprietary equipment expedites the preparation of proposals. Solid-state construction assures reliability. Off-the-shelf equipment can meet your speed requirement, with accuracies to .01% analog and .0001% digital. Packard Bell Computer engineers inspire confidence, whatever your problem may be — from process control to satellite orbit prediction. Talk with them and see.

PACKARD BELL COMPUTER HAS DESIGNED AND INSTALLED SYSTEMS FOR USE IN:

- Transmission and display of radar data
- Scanning of radar data and preparation for computer processing
- Providing linkage of analog and digital computers for simulation
- Components and systems checkout
- Telemetry data reduction—PAM, PDM, FM/FM, PCM
- Computer data entry and display
- Real-time simulation of missile problems
- Digital process control
- Geophysical exploration
- Mixture and flow control

pb Packard Bell Computer

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Whether your servo application is in the challenging under-water environments of the history-making Skate or in the severe blast-off environment of the Polaris, you now can design your equipment or system smaller and better with an IMC servo ■ New advances in sub-miniaturization and motor performance ensure top operating characteristics for your systems applications. Size 5 through 18, high torque-to-inertia ratio, encapsulated for extra ruggedness, broad range of gear ratios, meet latest MIL environmental specifications ■ IMC engineers are ready to assist you in your servo design needs. Take advantage of their special servo know-how. Chances are they will save you time and money . . . plus provide you with a motor that completely fulfills your particular requirements ■ Write for additional technical information to:

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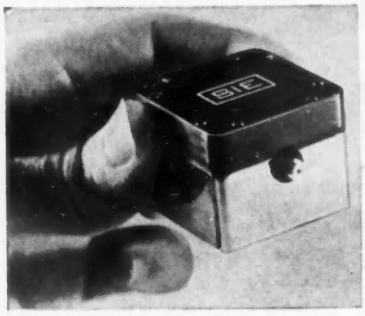
570 MAIN STREET/WESTBURY, LONG ISLAND/NEW YORK/EDGEWOOD 4-7070

NEW PRODUCTS

A single or both a high and low limit can be detected on each speed. The detector operates on speed alone, independent of voltage, load or other factors. Service life of 1.5 million cycles is claimed.—Torq Engineered Products, Inc., Bedford, Ohio.

Circle No. 328 on reply card



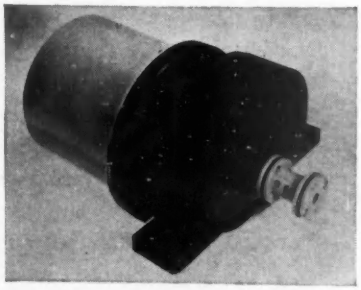
STABLE AND SENSITIVE

Claimed to be radically different from any vibration pickup yet offered, the TD-6 boasts a newly developed magnetic circuit that combines the sensitivity previously available only in fluid damped units with the temperature stability of magnetic damping.

Characteristics:

Size: 1½ in. square by 1⅝ in.
Weight: 6.5 oz.
Frequency range: 20-20,000 cps.
Threshold velocity: essentially zero.
List price: $175.00.
—Southwestern Industrial Electronics Co., Div. of Dresser Industries, Inc., Houston, Tex.

Circle No. 329 on reply card



HIGH SPEED INDICATORS

A new high speed position indicator system comprises a position sensor and a position indicator display. Accurate at speeds of 130 ft per min and accelerations up to 1 ft per sec², the standard model reads feet, inches, and

REGATRAN®
SEMICONDUCTOR
POWER SUPPLIES...

Here's reliability . . . Since their introduction, over 18 months ago, not one Regatran has lost a series transistor due to short circuits or overloading.

MODEL T036-5M

NOW... higher current REGATRANS

WIDE RANGE MODELS

MODEL NUMBER	D-C OUTPUT	
	VOLTS	AMPS
T060-15	0-60	0-15
T036-30	0-35	0-30
T032-30	0-32	0-30
T014-30	0-14	0-30
T07-30	0-7	0-30

Brief Specifications (all models)

REGULATION, LINE OR LOAD: 0.03% or 0.01 V (0.01% or 0.003 V available).

RIPPLE: Less than 1 millivolt rms.

CIRCUIT PROTECTION: (1) electronic circuit breaker plus (2) electromagnetic circuit breaker plus (3) input line fused.

NARROW RANGE MODELS ALSO AVAILABLE

REQUEST BULLETIN 721A (Revised) FOR COMPLETE SPECIFICATIONS

ELECTRONIC MEASUREMENTS
COMPANY OF RED BANK
RED BANK • NEW JERSEY

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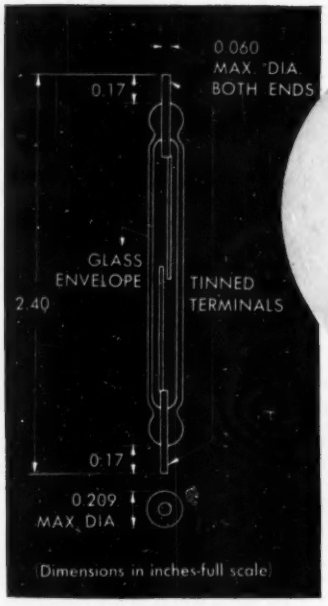
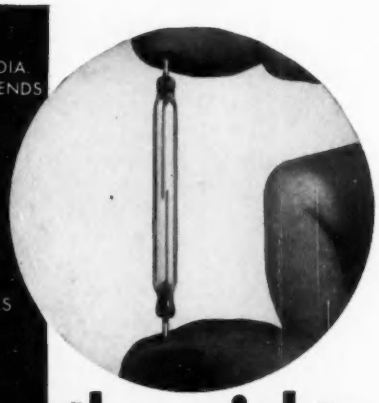




the mighty little glaswitch*

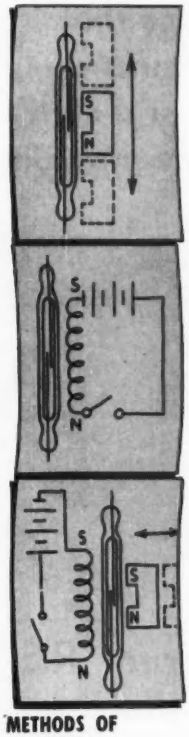
LIGHTNING RESPONSE . . . SEALED IN GLASS

The magnetically actuated reeds in this tiny Revere GLASWITCH make contact in just 1 millisecond . . . at rates up to 400 cycles per second. Hermetically sealed in an inert, dry atmosphere, with lightning fast snap action, both shelf and contact life are extremely long. Smaller than a cigarette, the GLASWITCH can be located anywhere . . . in any position . . . even in explosive atmospheres . . . individually or in multiples for multi-contact use.

Whenever you need faster, more positive response . . . where extreme sensitivity is a must . . . where light weight is important . . . investigate the Revere GLASWITCH. Write today for complete specifications.

CHARACTERISTICS:

Type—Single pole single throw—normally open—snap action
Enclosure—Hermetically sealed glass tube containing inert dry atmosphere
Operating Time—1 millisecond
Operating Rate—Up to 400 cycles per second
Contact Surfaces—Electroplated Rhodium
Contact Resistance (measured terminal-to-terminal)
Closed Circuit—0.050 ohms maximum
Open Circuit—500,000 megohms minimum
Contact Ratings
DC—Up to 1 ampere
AC—Up to 25 watts depending on application
Reliability and Life
No Load—Billions of operations
Rated Loads—No failures to open or close in first 100,000 cycles
Ambient Temperature Range: —320°F to +300°F



METHODS OF ACTUATION:

A moving permanent magnet or controlled external electromagnetic field are all you need . . . and the sky's the limit on imagination!

*Trade mark

1R

REVERE CORPORATION OF AMERICA
Wallingford, Connecticut
A SUBSIDIARY OF NEPTUNE METER COMPANY

neptune

NEW PRODUCTS

16ths of inches in a range from 0 to 100 ft. Sensor shown above can be connected to almost any linear or rotary moving member. Indicator numbers are ½ in. in a 7 in. high by 14 in. wide by 10¾ in. unit.—Sanders Associates, Inc., Nashua, N. H.

Circle No. 330 on reply card

CONTROLLERS, SWITCHES & RELAYS

TIMES BATCHES

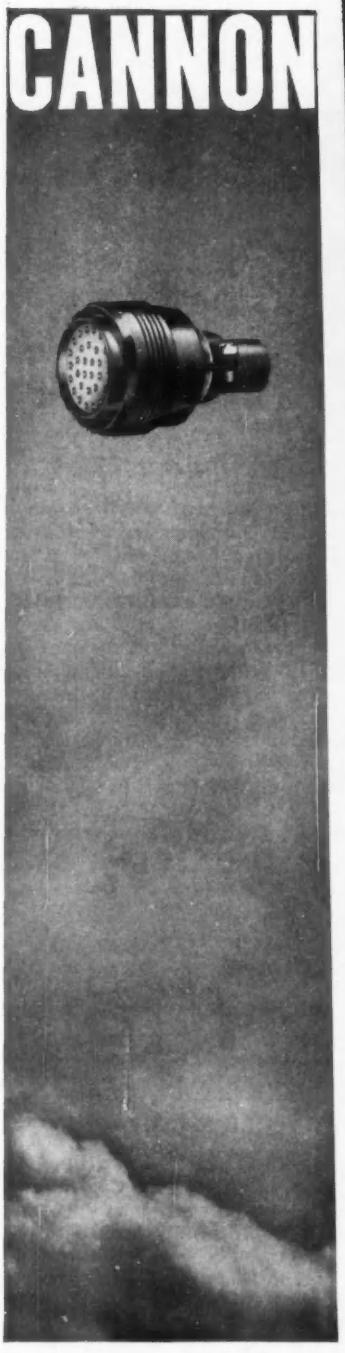
When installed in the circuit of a batch-type operation, the new Model 7003 will provide automatic regulation of either temperature or pressure (systems are interchangeable). Activation is by pushbutton; signal light indicates startup. As measured variable reaches control point, another indicator lights. After a preset time, controller shuts down and timer resets. Timer ranges are 1, 5, 12, or 24 hrs; minimum setting is 4 percent of range. Circular 12-in. chart indicates from 100 deg F or 30 in. Hg vacuum to as high as 1,000 deg F or 7,500 psi.—Weston Instruments Div., Daystrom, Inc.

Circle No. 331 on reply card

ACCURATE DELAY

The Model 50-129 time delay relay is a new highly accurate device, switching within a tolerance of ±0.2 percent or ±1 millisec. The relay features delay lines of 100, 250, or 450 millisec and operates from a 28-vdc power source. It switches up to 1 amp dc and is similar in operation to a 3-pole,

CANNON WEATHERPROOF PLUGS...



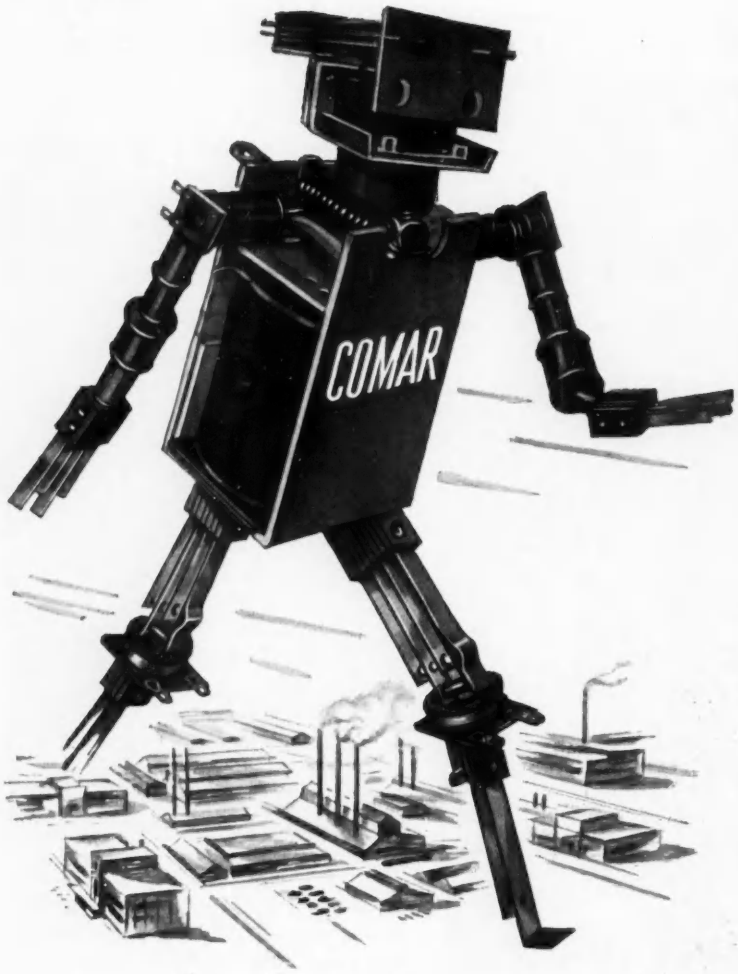
AVAILABLE NOW FOR ANY MOISTURE ENVIRONMENT

Wherever water threatens an electrical connection, you can be sure of positive dry contact by choosing from Cannon's many types of weatherproof plugs. For rocket engine test stands... ground support equipment... buried or exposed cables... underwater research equipment... or any wet weather condition... Cannon has the right plug for you. ■ Moistureproof types maintain sealed characteristics at high altitudes and over a wide temperature range. ■ Weatherproof types repel water under severe mud, ice, and water conditions. ■ Watertight types may be used underground and in swamps, lakes, and rivers... may be submerged in water up to 550 feet without leaking. Cannon's weatherproof plugs are another of many reasons why you should always consult the first name in plugs... why you should always consult Cannon for all your plug requirements. For information on Cannon weatherproof plugs, or any Cannon product, write to:

CANNON PLUGS

CANNON ELECTRIC COMPANY, 3208 Humboldt St., Los Angeles 31, Calif.

CIRCLE 157 ON READER SERVICE CARD 157



Need relays?
we'll come running–

● Producing relays fast and at low cost is a Comar specialty. Our complete engineering and manufacturing facilities are geared to save you time and money. Whatever type relay you need, simple or complex, industrial or military, Comar can serve you best. Write: Comar Electric Company, 3349 Addison Street, Chicago 18, Illinois.

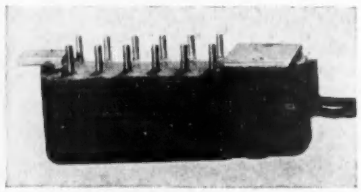
Comar Electric

RELAYS • SOLENOIDS • COILS • SWITCHES • HERMETIC SEALING

NEW PRODUCTS

single-throw relay. The unit is said to have an operating life of 1,000 hours; it measures 3 x 3 x 3 in.–Electronics Dept., Hydro-Aire Co., Burbank, Calif.

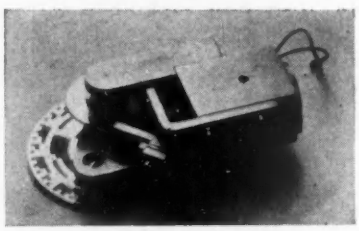
Circle No. 332 on reply card



SIX-SWITCH SQUIB

Originally designed by the Army's Diamond Ordnance Fuze Labs, the XM-9 switch is believed to be the smallest of its type and capacity– 2 x 1 x ⅝ in. (l x h x w). It weighs 1½ oz. Six pairs of normally closed contacts touch conducting rings on a shaft. When an M-4 dimple motor is actuated, its internal gas pressure punctures a diaphragm, allowing the shaft to move and break all six circuits. Function time is 4 to 5 millisec.– Dial Service and Mfg. Inc., Cleveland, Ohio.

Circle No. 333 on reply card



MINIATURE SEQUENCER

The solenoid actuated switching device shown above is designed to program events in sequence in solid state circuits over a wide range of input rates. An interchangeable coded disc is used to determine the sequence of events. Weighing only 0.9 oz, the programmer is only 1¾ in. long.–Elgin Micronics Div., Elgin National Watch Co., Elgin, Ill.

Circle No. 334 on reply card

MICRO-SENSITIVE

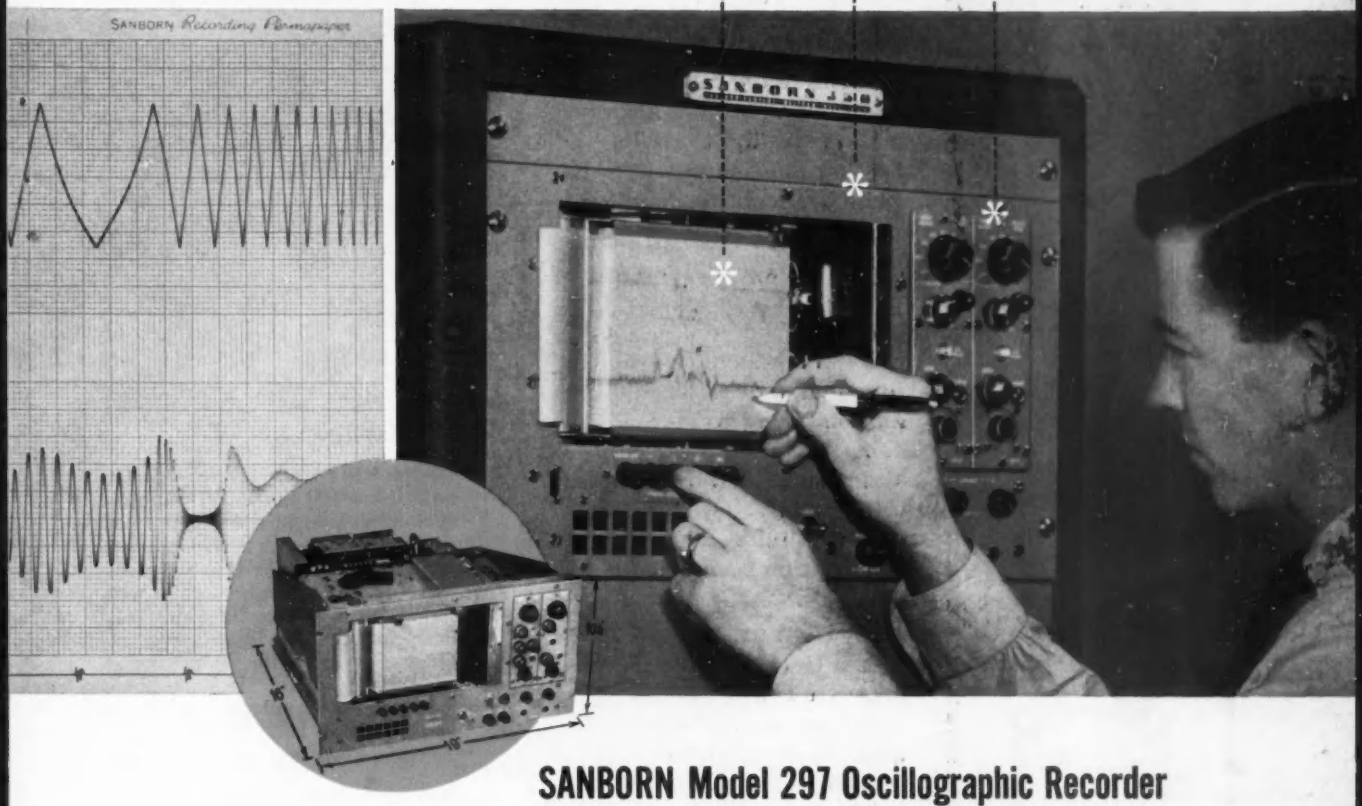
A proximity switch in the price range of limit switches uses a single beam which rocks on a single pivot. Beam is held in place by a magnetic force

has easily read 50 mm wide, rectangular coordinate channels

mounts in 10½" of rack space or in a separate portable case

interchangeable "850" Series plug-in preamplifiers for each channel

THIS NEW 2-CHANNEL DIRECT WRITER...



SANBORN Model 297 Oscillographic Recorder

Compactness and versatility without loss in performance is the design concept for this new 2-Channel Direct-Writer from Sanborn. The Model 297 provides two *complete* recording channels in only 10½" of panel space, making it extremely useful as a monitoring recorder — integrated with large instrumentation setups in data processing installations, test stands and similar applications. In its own portable case, the Model 297 will be equally useful in *laboratories and field applications* as a bench-top instrument.

Preamplifiers are "850" Series plug-in interchangeable units, available in Carrier, DC Coupling, Phase Sensitive Demodulator, and Low Level types. They may be used in any combination, one for each channel. An internal MOPA for carrier and chopper excitation is also available.

The basic recorder assembly houses a preamplifier power supply, transistorized power-amplifier power supply, and two transistorized current-feedback power amplifiers with *built-in electrical limiters* that provide damping at all times. The entire unit has built-in forced filtered air cooling.

The recording mechanism has rugged, enclosed galvanometers with velocity feedback damping . . . 4 different chart speeds selected by push buttons . . . timer/marker stylus with 1 second timer . . . approximately 6 inches of visible chart with immediately visible traces made by heated stylus. The electrical and mechanical specifications in combination with the many "big system" operating features make the compact Model 297 one of the most useful, reliable 2-channel direct writers available.

Contact the Sanborn Sales-Engineering representative nearest you or write the main office in Waltham for complete information and application assistance. Sales-Engineering representatives are located in principal cities throughout the United States, Canada and foreign countries.

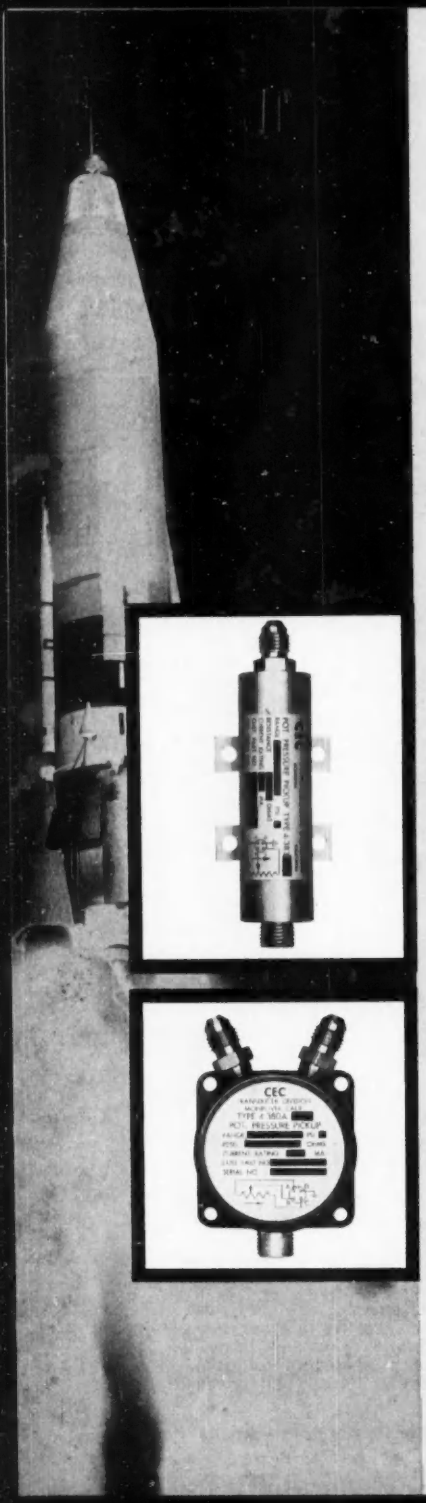
Model 297 2-Channel Recording System Specifications
(Less plug-in preamps)

Sensitivity: 0.1 volt/mm nominal
Frequency Response: DC to 125 cps within 3 db, 10 mm peak-to-peak amplitude
Gain Stability: Better than ½% from 20°C to 40°C or line voltage change from 103 to 127 volts
Linearity: Max. non-linearity is 0.2 mm
Electrical Limiting: Approximately ±115% of full scale
Chart Speeds: 1, 5, 20, and 100 mm/sec. by mechanical push button
Dimensions: 10½" high x 16" deep x 19" wide
Paper Take-up: electrically operated

(Specifications are subject to change without notice.)

SANBORN COMPANY
Industrial Division
175 Wyman Street Waltham 54, Massachusetts

CIRCLE 159 ON READER SERVICE CARD



TWO POTS

for missile pressure measurement

Here's a rugged pair—one for low pressures and one for high pressures—that can really take shock and vibration. That's why *accurate* in-flight missile pressure measurement is their particular specialty.

THE HIGH-PRESSURE 4-383 comes in gage and absolute models that measure pressure from 600 to 3500 psi. It's a helical Bourdon tube instrument, oil filled and featuring welded construction of 304 stainless steel (no gaskets or O-rings)... fail-safe case that takes 5000 psi ...vibration resistance to 35 g's.

THE LOW-PRESSURE 4-380A uses a force-summing pressure capsule and a pot to measure absolute, gage, or differential pressures from 0 to 100 psi. It features a balanced dual flexure pivot for extreme resistance to the effects of shock and vibration.

You'll want more information on these pot pressure transducers that operate in a range of −65°F to +200°F—with resistance of 5000, 7500, and 10,000 ohms. Write for Bulletins CEC 1604-X26 and 1625-X1, or provide us with your exact requirements for a custom-engineered instrument.

Transducer Division CEC

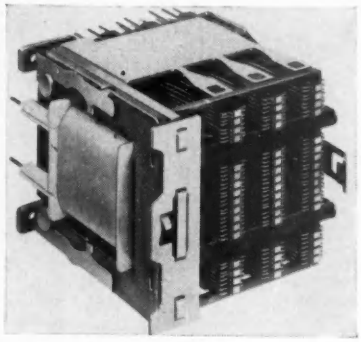
CONSOLIDATED ELECTRODYNAMICS / pasadena, california

A SUBSIDIARY OF Bell & Howell · FINER PRODUCTS THROUGH IMAGINATION

NEW PRODUCTS

which is opposed by a coil spring. The operating element diverts the magnetic force, releasing the contact beam. Switch is rated at 6 amps at 110 volts resistive load and 3 amps at 220 volts. Price is $17.50.—Tann Controls Co., Div., Tann Corp., Detroit, Mich.

Circle No. 335 on reply card

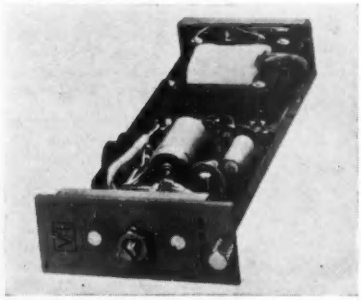


WIRE-SPRING RELAY

Designed to transfer up to 51 circuits quickly for 100 million or more operations without adjustment, this new wire-spring relay uses a unique actuating card—activated by armature movement—to operate all moving wire-spring contacts simultaneously and independently. Available in a variety of arrangements with various operating voltages, a full 51-circuit, three-level relay will sell for $50.—Automatic Electric Labs., Northlake, Ill.

Circle No. 336 on reply card

POWER SUPPLIES



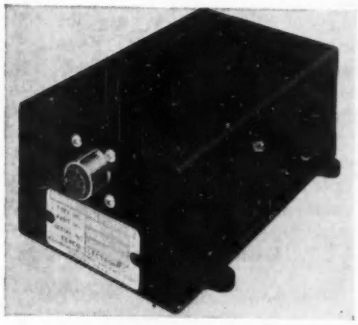
SMALL PACKAGE

Featuring 0.1 percent regulation, a new isolated strain gage power supply takes up very little space. Output of

←CIRCLE 160 ON READER SERVICE CARD

the solid state unit is floating, at an internal impedance of less than 0.2 ohm. Noise to ground is less than 10 microvolts peak to peak when measured with a 350-ohm bridge. Leakage resistance exceeds 10,000 megohms. Price: $68.—Video Instruments Co., Inc., Santa Monica, Calif.

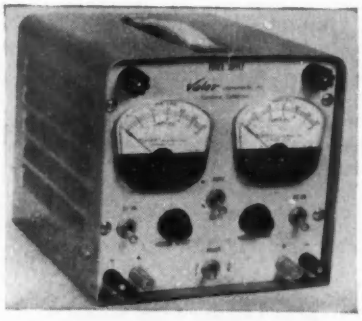
Circle No. 337 on reply card



EXCEEDS REQUIREMENTS

This new dc-dc converter exceeds the requirements of most telemetry applications for regulation, output noise, and efficiency. Efficient regulation is achieved by supplementing the input dc line voltage with a regenerative feedback voltage from the oscillator. A minimum of 70 percent efficiency is obtained at 24-32 vdc input with output regulation of plus or minus 3 percent at 250 vdc (250 ma), plus or minus 1.5 percent at 150 vdc (100 ma), and plus or minus 0.1 percent at 5 vdc (100 ma).—Temco Electronics, Div. of Temco Aircraft Corp., Dallas, Tex.

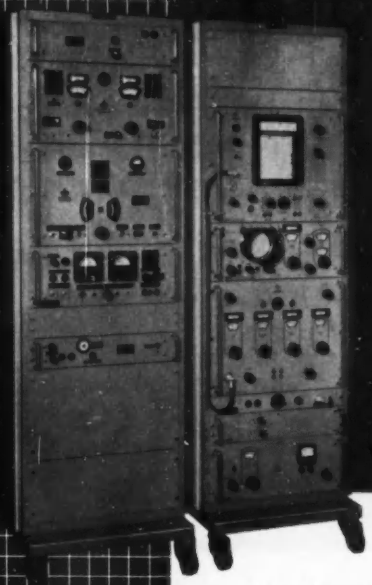
Circle No. 338 on reply card



RESETS AUTOMATICALLY

Instantaneous electronic lock-out with automatic reset is available in a new twin power supply, featuring a fail-proof protective system. Transistor failures, experienced with electronic current limiting and fuse and circuit breaker protective systems, are eliminated. Damage from temporary overload is eliminated through the use of

WITH ITT
FREQUENCY SYNTHESIZERS



CRYSTAL ACCURACY TO 30 KMc/s

Here is error-free synthesis of any frequency over an extremely wide range. Using a standard 100 Kc/s source, the versatility of this instrument is virtually limitless for applications requiring precise frequency measurements and control. And because the system can be designed from a variety of existing instruments, you buy to fit your exact applications.

For example, start with the basic ND-5 Frequency Decade for basic middle-range measurement from 1 Kc/s to 30 Mc/s. Then, as the needs arise, add interpolation oscillators . . . frequency multipliers . . . aperiodic output amplifiers . . . frequency comparison oscilloscopes . . . frequency drift recorders . . . spectrum analyzers. All are built to ITT standards by Schomandl, world leader in decade frequency synthesizers.

For complete specs and application data, contact your ITT Instrument representative, or write us direct for Data File CE-1043-1.

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Here's an

EYEFUL of technical data on precision resistor and potentiometer wire

Two new catalog-manuals containing complete information on

TWO NEW HOSKINS 800 OHM ALLOYS

If you make potentiometers or precision wire wound resistors, these manuals are meant for you! They're loaded with helpful technical information—show all physical properties and electrical characteristics, list bare and enameled wire specifications. And they contain much useful application data compiled especially to help you produce more and better control components with these two new performance-proved alloys:

Chromel-R: A modified 80-20 type nickel-chromium alloy possessing electrical resistivity of 800 ohms per cmf at 20° C., low temperature coefficient controlled within 0 ± 10 ppm per °C.—plus exceptional linearity and stability from −65° to +150° C.

Alloy 815-R: A lower density, higher resistivity fe-cr-al material that gives you 14% more ohms per pound. Has good strength and ductibility, excellent resistance to wear and corrosion. Resistivity is 815 ohms per cmf at 20° C., temperature coefficient 0 ± 10 ppm per °C. in the range from −65° to +150° C.

Send for copies today—plus samples of both alloys!

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Producers of Custom Quality Resistance, Resistor and Thermo-Electric Alloys since 1908

162 CIRCLE 162 ON READER SERVICE CARD

NEW PRODUCTS

variable current limiting; short-circuit damage problems are solved by a shut-off which automatically resets itself

Characteristics:

Outputs: Two, each 6-30 vdc @ 0.5 amp
Transient response: 35 mv for 50 microsec or less
Line regulation: ±1 mv
Load regulation: 50 mv for 0- to 0.5-amp load change
Ripple: 300 microvolts rms
Dimensions: 7 x 7 x 8 in.
Input: 105-125 volts, 60 or 400 cps —Valor Instruments Inc., Gardena, Calif.

Circle No. 339 on reply card

BATTERY POWER

Five different power combinations for operating missile instrumentation and control are available from a new silver-zinc battery. Sections provide 28 volts at four current levels from 0.5 to 14 amps, and a 6.5-volt section provides 6-amp current. Activation of the sections is automatically provided by an electrolyte tank and piston arrangement. A solid propellant gas generator forces the electrolyte into the cells.—Cook Batteries, Subsidiary of Telecomputing Corp., Denver, Col.

Circle No. 340 on reply card

PLUS. . .

(341) Boasting only 0.2 percent rms ripple, a new 100-amp, magnetic amplifier-regulated **dc power supply** is now available from **Perkin Engineering Corp., El Segundo, Calif.** . . . (342) Designed for high output in a compact package, **this new transistorized supply from Mid-eastern Electronics, Inc., Springfield, N. J.,** provides both 6 and 18 vdc at 30 amps.

Circle No. 341 or 342 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS

FOR PROCESS AND POWER

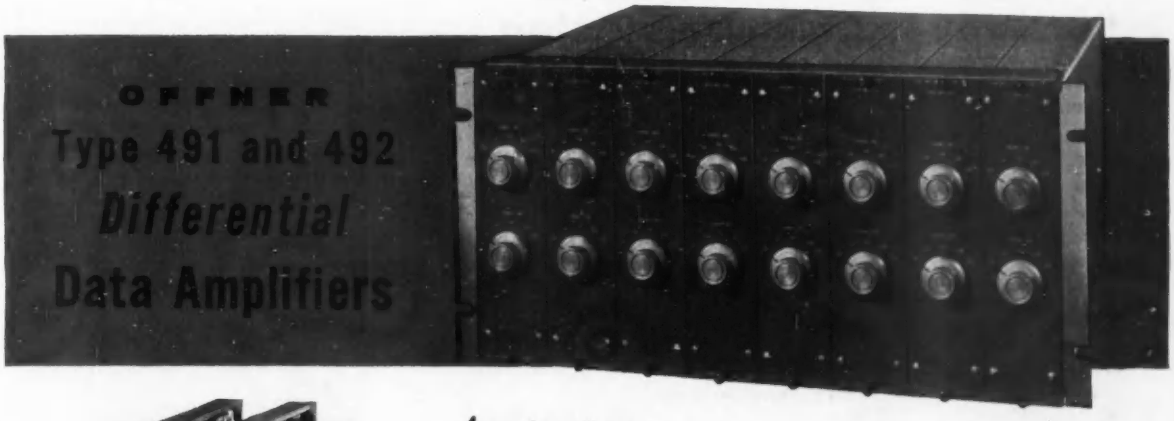
Features of a new line of single seated control valves include high capacity, ability to handle high pressures, and

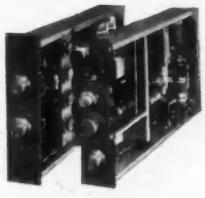
Two completely new, transistorized, differential Data Amplifiers, Types 491 and 492, by Offner Electronics Inc. Their high precision makes possible an accuracy and simplification of data reduction previously impossible. Sixteen channels of data reduction (Type 492) requires only 8¾" of rack space. Power supply occupies only 5¼". The combination of accuracy, stability, fast response, and size is unmatched.

1/100% accuracy

1/100% gain stability

1/100% linearity





Type 492 Amplifier (left) provides 2 channels of precision amplification per unit. The Type 491 (right) is a single channel unit, with input coupler for added versatility.

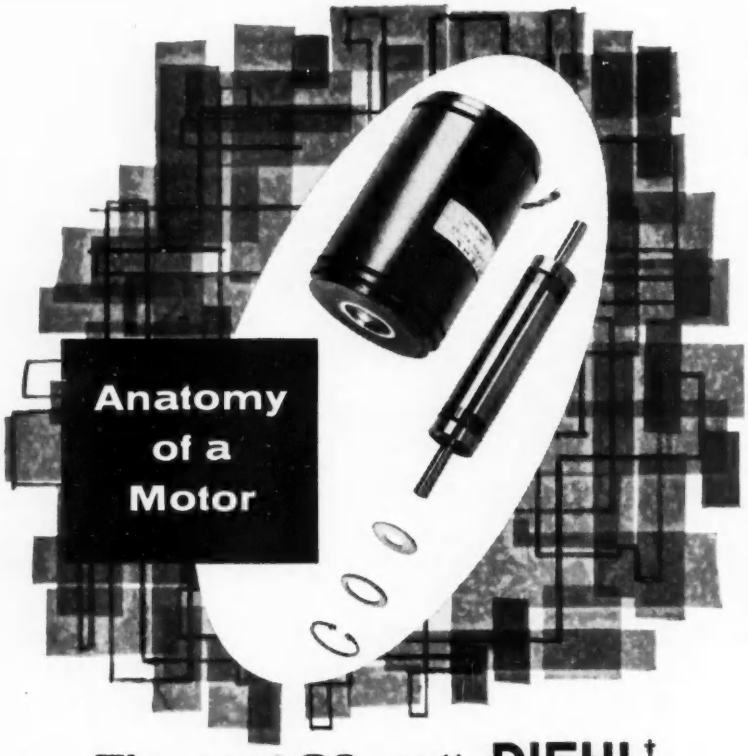
featuring

1/100% accuracy

1/100% gain stability—for 1,000 hours at normal ambients
1/100% linearity—for full output
All-transistor construction
1/400th second response—to step input
Very low output impedance—less than 0.1 ohm
Infinite rejection—of common d-c signals
120db rejection—at 60 cps
16 channels in 8¾ inches of rack space (Type 492)
Versatile input couplers (Type 491)

OFFNER ELECTRONICS INC.
3904 River Road, Schiller Park, Ill. (Suburb of Chicago)

CIRCLE 163 ON READER SERVICE CARD 163



The new 20 watt DIEHL† Instrument Servomotor a study in practical design

A carefully constructed winding—set in a round, die cast aluminum housing and totally encapsulated with a protective epoxy resin . . . a low inertia ingot-iron rotor . . . and two sets of prelubricated ball bearings . . . a simple anatomy. Yet these few simple parts combine to make the new 20 watt DIEHL Instrument Servomotor the most practical servomotor ever designed for commercial applications . . . because all costly construction features and environmental precautions which are unwarranted in a commercial application have been eliminated. But full performance and all essential environmental precautions have been retained . . . including moisture, salt, and fungus proofing, good resistance to shock, safe operation in ambients of —55 to +55°C, and these other outstanding performance characteristics:

SPECIFICATIONS AT STALL

Cat. No.	FPE49L-116-1
Output	20 Watts
Voltage (per phase)	115 Volts
Frequency	60 Cycles
Torque	25 oz. in.
Input power (per phase)	54 watts
Control phase impedance	174 ohms
No Load Speed	3500 R.P.M.
Inertia (Wk2)	.725 oz. in.^{2}
Theor. acceleration	13,300 rad/sec.^{2}
Weight	2.75 lbs.
Motor Transfer Function	$\frac{3.2}{S\ (.028S + 1}$
Frequency response	5.75 cyc./sec

Write for more information on our complete line of instrument servomotors. Available in sizes 11 and 15, power ratings from 1 to 20 watts.

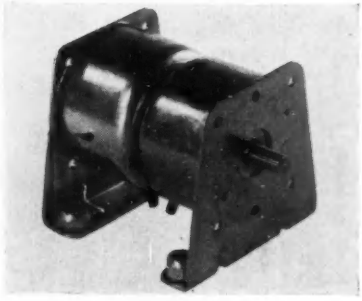
DIEHL MANUFACTURING COMPANY
A SUBSIDIARY OF THE SINGER MANUFACTURING COMPANY
Somerville, New Jersey

†A Trademark of THE DIEHL MANUFACTURING COMPANY *A Trademark of THE SINGER MANUFACTURING COMPANY

NEW PRODUCTS

a wide selection of reduced capacity trim. Engineered expressly for process and power plant applications, the 20000 series is available in sizes from ¾ to 10 in. with ratings in iron of class 125 or 250 ASA and in steel of 150 to 2,500 lb ASA.—Mason-Neilan Div., of Worthington Corp., Norwood, Mass.

Circle No. 343 on reply card



SIZE 5 STEPPER

A new Size 5 Digimotor for use as a stepping motor or indexing device is available with 8, 10, 12, 18, 20, and 24 steps per rev. Uni- or bidirectional models with or without detent are made. Stepping rate is 15 to 25 steps per sec, depending on number of positions, load, and other factors. Any duty cycle within an operating range from 6 to 350 vdc is available.—Ledex, Inc., Dayton, Ohio.

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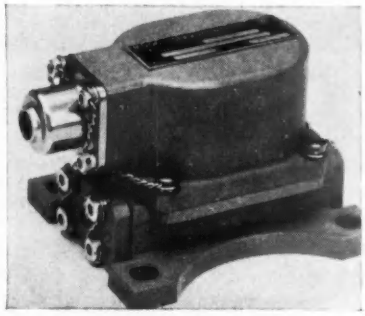


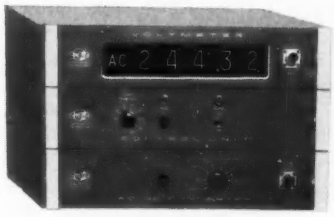
SCALED DOWN PERFORMER

The Series 30 electrohydraulic servovalve is identical in operation to the manufacturer's proven Series 31 line. In a miniaturized form now, weighing only 5.12 oz, the device features the nozzle-flapper hydraulic amplifier and mechanical feedback arrangement of

ELECTRONICALLY speaking.....

CUBIC DIGITAL SYSTEMS

speak for themselves:



.003%

DC VOLTAGE MEASUREMENT: Models V41, V51, with Control Unit C-1

AC VOLTAGE MEASUREMENT: Models AC-1 (manual ranging), AC-2 (Automatic) AC Converters

RESISTANCE MEASUREMENT: Models 0-41, 0-51 4 and 5-digit Ohmmeters, with Control Unit C-2

VOLTAGE RATIO MEASUREMENT: Models R-41, R-51 Ratiometers, Models VR-41, VR-51 Volt-Ratiometers

INPUT SAMPLING: Model MS-2 100-point Scanners, Models MS-1, AS-1 Master-Auxiliary 1000-point Scanning Systems

DATA RECORDING: Model PC-Series Printer Controls for use with any quality printer on the market

Cubic Corporation manufactures *the superior* digital instrumentation, including the Voltmeter with these unparalleled electronic features:

.003% repeatability, precise accuracy again and again

.003% attenuator accuracy for wide-range precision

.003% bridge linearity with carefully matched quality components

PLUS maximum noise rejection with the finest input filter known ... and unmatched stability through superior noise rejection.

The Cubic 4 and 5-digit Voltmeters are only two of the superior instruments in a line of digital instrumentation available on an off-the-shelf basis for simple bench use or for easy development of sophisticated systems for measurement and recording.

NEW FROM CUBIC . . .

The Talking Meter, instrumentation that really does speak for itself, instrumentation that provides a new dimension in "readout," measurements or other parameters reported to the ear by a clear human voice.

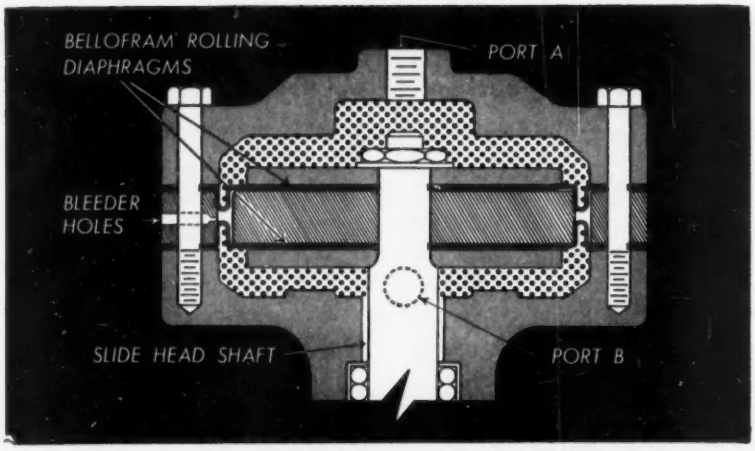
CUBIC CORPORATION

INDUSTRIAL DIVISION

5575 Kearny Villa Road, San Diego 11, California

Years-ahead engineering, factory production techniques inspired by pride in the end result, careful quality control and reliability testing . . . all these factors make Cubic's the truly fine instrumentation . . . Digital Systems that speak for themselves.

Electronic Engineering With a Dimension for the Future



Air pressure entering double-acting cylinder at Ports *A* and *B* actuates slide head shaft, which controls positioning of upper electrode. Sensitive low inertia response is achieved by two frictionless Bellofram Rolling Diaphragms. Bleeder holes maintain a pressure differential.

Frictionless Rolling Diaphragms Insure Fast Follow-up for Welder

PROBLEM: To design, for use in an automatic welding machine, a pneumatic actuator for positioning the upper electrode in response to expansion or contraction of the weld nugget. Sensitive, frictionless movement was mandatory to provide instantaneous reaction to momentary changes in nugget dimensions.

SOLUTION: Federal Machine & Welder Company's designers specified a double-acting air cylinder with two Bellofram Rolling Diaphragms, each molded from a dacron fabric impregnated with a nitrile elastomer.

With no mechanical spring gradient, no break-out friction effects, and low hysteresis, these rolling, non-porous membranes instantly translate pressure changes into movement of the electrode control head. Although very sensitive to pressure variations, they are capable of sustaining high working pressures, because the force experienced on the narrow convolution is only a small fraction of the total force applied over the effective pressure area.

Operating between wide temperature ranges, these Bellofram Rolling Diaphragms provide a flex life of millions of cycles, yet do not require lubrication or close machine fits for piston and cylinder.

Bellofram Rolling Diaphragms are free positioning and friction-free. They roll off the piston sidewall and onto the cylinder sidewall in a smooth, continuous motion.

WHAT IS YOUR PROBLEM?

If conventional bellows, O-rings, cup packings, etc., fall short of your requirements, Bellofram Rolling Diaphragms may be the answer. Special types can be designed for use with almost any gas or fluid in actuators, pumps, instruments, seals, accumulators, fluid dampers, etc.

OPERATING LIMITS

Operating Pressures: 1 inch H_2O to 500 psi (up to 1200 psi in some cases).

Operating Temperatures: −85°F. to +550°F. (from −120°F. to +700°F. in some cases).

Cylinder Bore Sizes: .25 to 12 inches.

Effective Pressure Area: .028 to 108 square inches.

Total Stroke Capabilities: .01 to 12 inches.

Sidewall Thickness: .008 to .035 inches.

Send for free literature

nothing rolls like a Bellofram® rolling diaphragm

BELLOFRAM CORPORATION, 29 BLANCHARD RD., BURLINGTON, MASS.

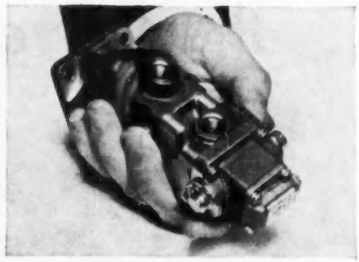
BRowning 2-2100 Mission 3-9000 Teletype No. Burl., Mass. 166

®Reg. trademark U.S.A. and foreign countries • Bellofram Rolling Diaphragms are protected by U.S.A. and foreign patents.

NEW PRODUCTS

the 31 valve. Maximum flow capacity is 3 gpm at 3,000 psi–adequate for most low flow control systems.–Moog Servocontrols, Inc., East Aurora, N. Y.

Circle No. 345 on reply card

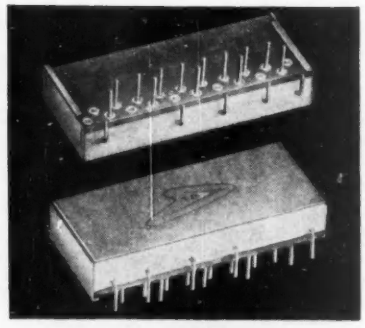


IN ONE PACKAGE

Weighing only 2.7 lb, this new servovalve-hydraulic motor combination occupies just 60 cu in. Differential current of only plus or minus 8 ma actuates the valve control spool. The valve modulates flow to the motor, producing speeds between 10 and 20,000 rpm with maximum output running torque of 30 lb-in. at 3,000-psi supply pressure.–Vickers, Inc., Div. of Sperry Rand Corp., Detroit, Mich.

Circle No. 346 on reply card

COMPONENT PARTS



UNIVERSAL MODULE

Featuring versatility, compactness, and ruggedness, the Type 6000A logic module is suitable for a wide range of applications in digital systems and test equipment. The device contains two solid state switching circuits and

New "Packaged" Protection for Pneumatic Systems

Meet the F-30 ■ Non-clogging trap saves money ○ Refrigerate for driest air ●

■ "Packaged" Protection, Jr.

That's the new Hankison Model F-30 Refrigifilter, designed to give *medium capacity* pneumatic systems micro-clean, dehydrated, oil-free compressed air . . . protect them from the rust and sludge conditions that lead to malfunction and equipment failure. It's rated at 30SCFM, gives you a dew point as low as 40°F *at pressure*. Like its older brother, the F-100, it requires no cooling water, eliminates problems caused by ambient temperature variance. Pressure drop across the unit does not exceed 1½ PSIG.

The new F-30 combines the functions of a condenser, separator, filter, and trap (internal or external), in a package just 35" high. It discharges *cool*, dry air—exit air temperature is 52°F at rated capacity and 75°F ambient temperature.

Ask today for the full story—just use the coupon at right.

○ The Finish Started It All

One of the world's leading manufacturers of laboratory furniture is particularly noted for his handsome, long-lasting surface finish, sprayed on with meticulous care. Water in their air lines is intolerable—and of course, very expensive in terms of refinishing costs. The answer seemed to be a condensate trap, but none of several tried could handle the emulsified oil from the compressor, without plugging up. Then, about two years ago they started to use a Hankison Mag-Pneu-Power Automatic Trap. The result? They're getting "perfect service" to use the Plant Engineer's words, and their Mag-Pneu-Power Trap has never required other than routine attention.

Hankison Mag-Pneu-Power Automatic Traps use the actual pressure in your pneumatic systems to accomplish split-second discharge. A large, ½" orifice accounts for their non-clogging feature, and for the occasional cleaning that's required, you simply open a blowdown petcock in the housing. They are used to discharge condensates and entrainments from all types of compressed air and gas lines, and to lend valuable assistance to air and gas dehydrating equipment. Stainless steel models are available for corrosion applications.

The coupon below will bring you full information.

● Refrigeration Air Drying Rated Superior by the Experts

Authorities on pneumatics say that the best air cleaning and drying is done by mechanical methods, and that the best mechanical methods base their efficiency on refrigeration.

Of all methods employing refrigeration, we maintain that Hankison Refrigifilters are unsurpassed, for these reasons: They are compact, completely integrated, ASME Coded "packages" employing closed-loop refrigeration cycles to obtain their low dew points and to eliminate problems of ambient temperature variance and need for cooling water. Condensate—oil and moisture vapor as well as entrained liquids—is discharged through the Mag-Pneu-Power Trap. Solid contaminants are removed by the specially-designed filter cartridge.

Refrigifilters are available in two models—the new F-30, described at left, and the F-100, (shown above, installed) which delivers—30°F atmospheric dew point, has a rated operating pressure of 300 PSIG.

For full details on the F-100, use the convenient coupon below.

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The Controller, developed by Bendix Research Laboratories in collaboration with Bendix-Pacific, produces thrust proportional to an electrical signal by discharging compressed nitrogen through the nozzle. The Controllers are installed in pairs to stabilize each of the three axes.

The model illustrated, which weighs only 17.5 ounces, incorporates a 2-stage pressure control valve and has a maximum thrust capacity of 20 pounds. Other configurations are available.

Complete information is available on request.

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can be interconnected to form all the major building blocks needed in a digital system. In a $2\frac{1}{8}$ x $\frac{7}{8}$ x $\frac{3}{8}$-in. unit, the module contains a four-input diode gate, an inverting amplifier, and a pulse generator. Either singly or combined, the module can function as a NOR gate, flip-flop, binary counter, delay flop, or shift register stage.—Tele-Dynamics, Div., of American Bosch Arma, Philadelphia.

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The new square wave filter shown above is capable of maintaining a constant insertion loss to within 0.1 db over an input signal range of 0-20 volts rms. Designed to convert 30-cycle, 60-volt peak-to-peak square wave input into a sine wave with less than 1 percent distortion, the LF-125 is available in two models: with 50k or 100k input impedance.—Control Electronics Co., Inc., Huntington Station, N. Y.

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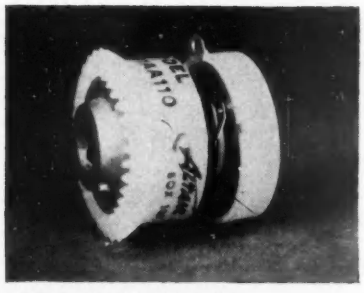

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474—The Uses of Digital Computers, $3.00

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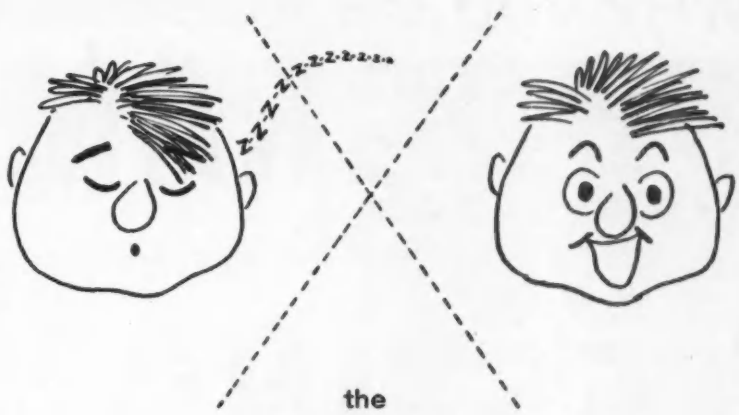
• • •

Control bits

Long Island Section of IRE is inviting papers for a symposium on adaptive control systems to be held at the Garden City Hotel, Garden City, L. I., October 17, 18, and 19. Sessions will cover definition of problem, analytical techniques, theoretical work, and application.

•

Manchester University has established the first full professorship in computer engineering in England. First appointee: Dr. Tom Kilburn who was largely responsible for the design of Mercury, built by Ferranti and considered the most powerful British digital computer in operation.



the
importance
of being

BISTABLE

(*especially if you're a transistor driving a relay*)

If you've been toying with the idea of using a transistor circuit to drive a relay, here are some facts of life that may save you grief later on. The watchword is bistable operation — particularly with regard to the transistor.

What can make a mess of an otherwise compact, cool, low standby-power transistor is a driving circuit that leaves the little pill neither saturated nor cut off. The transistor is then very apt to become an unstable, variable gain amplifier, when it should be taking a firm stand in favor of either "on" or "off". The thing to do is design the input circuit properly so that *it* is responsible for the transfer from one stable state to the other. (The Schmitt trigger circuit is an excellent for instance.)

Once you've got the transistor operating as a flip-flop and not as an amplifier, a good relay to use is a bistable type. Then the relay simply monitors the condition of the driving circuit, and success is practically around the corner (maybe). Magnetic latching relays are just such switches — and they have the added advantage of needing no standby power. Naturally, we have all sorts and kinds which all carry the designation "Form Zzzzz."

You won't be completely out of the woods, however, until you've given some thought to (a) operating speed and (b) nature of the transistor load. As for the former, you may be on the verge of transistorizing a tube-relay circuit and wonder why, all else being equal, the relay will operate slower from transistors. Although the transistor will do all sorts of wonderful things on less power, one thing it won't do on less power is hurry the relay. The remedy is adding some external resistance and raising the source voltage — or lowering the impedance of the relay. As for the load the transistor must switch, it is well to remember that if it's inductive (and a relay coil is) and the energy cannot be safely dissipated in the transistor, you'd better find another outlet. The lack of "arc suppression" in transistor circuits, when needed, may not produce juicy blue sparks but the result is the same — quite rapidly.

Some of our application engineers are notoriously bistable, and depending on which state they are in when they hear from you, will undoubtedly send you either (+) circuit design ideas (based on the use of a Sigma relay) or (−) some zzzzz-inducing printed material on bistable applications. Zatisfaction guaranteed.

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CIRCLE 173 ON READER SERVICE CARD 173

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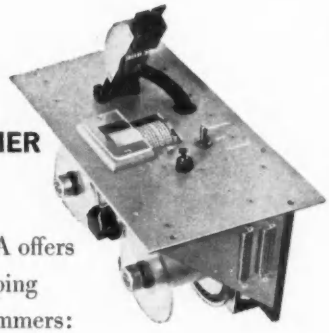
THIS BETTER WAY

WITH EECo's UNIQUE 80-BIT BI-DIRECTIONAL PUNCHED TAPE PROGRAMMER



For automatic programming of test equipment, the EECo TP-201A offers these decisive advantages over stepping switches or single-line 8-bit programmers:

(a) Far more elaborate programs can be automated...up to 240,000 bits per reel, presented at 80 bits per step. (b) Random or sequential access to any of the 3000 frames on each 250-foot tape. (c) Provision for visual selection of program step. (Printed information on tape correlates with punched information). (d) Reduced training time and skill requirements for tape punch personnel. (e) Programs can be stored and re-used. (f) Small size panel is 6″x11¾″, depth below panel 5¾″.

Tough Mylar tape contributes to improved reliability. No special punch needed. Bi-directional electrical drive system. Positive detent action for accurate positioning of tape.

Other models available for automatic programming, process control, and precision time base programming. Write for data sheet.

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NEW PRODUCTS

plus 85 deg C. Drive is by a 1-in. pitch diameter precision nylon bevel gear. Threaded slip ring and ¼-in. bore make the clutch particularly suited to driving potentiometers. Coil voltages range from 6 to 110 vdc.—Altair Research & Mfg. Co., Baldwin Park, Calif.

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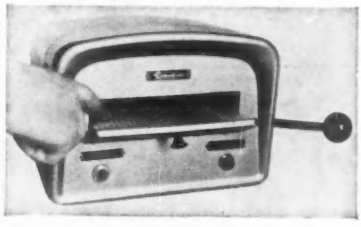
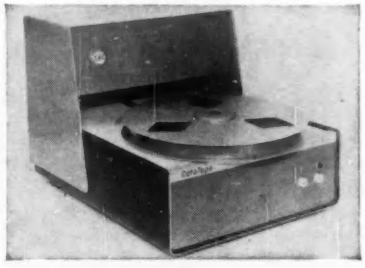


STATIC CARD READER

Now available as a standard component for use in controlling plant or machine operations, this static card reader reads all 960 holes of a standard IBM card; the card is stationary in the reader. The reader controls operations in progressive steps and can be built into various automatic machines or processes.—Richardson Scale Co., Clifton, N. J.

Circle No. 350 on reply card



DEGAUSSES AUTOMATICALLY

The type 5-055A automatic tape degausser can be used with tapes from ¼ to 2 in. wide on reels from 7 to 14 in. diam with all reel hubs. Tape recorded to saturation level can be erased to at least 50 db below normal record level. Automatic time cycling in the magnetic field achieves uniform

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TO: Engineers and technical management men actively engaged in aero space research and development, and production

FROM: The editors of CONTROL ENGINEERING

SUBJECT: August special report on aircraft, missile, and rocket *Guidance Systems*

This pace-setting study presents the first authoritative "round-up" of five basic guidance techniques and their effects on systems. Inertial . . . celestial . . . Doppler . . . radar and radio . . . each treated by a practicing specialist . . . probed for its advantages and shortcomings . . . present and possible uses.

Charts show which companies are doing what in each technique, and what they have on the drawing boards. The opening article is by the report's noted coordinator, Dr. Charles Mundo, manager of Systems Dept., Advanced Development, Raytheon Co.

This is valuable informatoin you don't want to miss . . . data that fills a vital gap in the basic literature of aerospace research and development. And there's only one way to get it . . . with a subscription to CONTROL ENGINEERING. So enter your subscription NOW . . . Turn to the Reader Service Dept. starting on page 169 for a subscription application card—mail it today . . . and you'll be sure a copy of this special issue is reserved in your name when it comes off the press in August.

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Edited by A. RALSTON, *Bell Telephone Labs, and* H. WILF, *Univ. of Illinois.* The only book on numerical analysis for digital computer users. Covers over 20 cases step-by-step, from problem analysis through program planning, flow chart construction, coding procedure, and de-bugging. *1960. 293 pages. $9.00*

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NEW PRODUCTS

degaussing. Complete cycle takes about 60 sec. Machine weighs approximately 80 lb and measures 15 x 16 x 22 in.—DataTape Div., Consolidated Electrodynamics Corp., Subsidiary of Bell & Howell Co., Pasadena, Calif.

Circle No. 351 on reply card

TRAINING AID

Designed to help teach digital techniques this new unit uses control panel patch cords to permit formation of adder-subtractors, shift registers, binary counters, and binary coded decimal counters. Switches choose from continuous operation, single pulse operation, or single cycle of addition or subtraction. Switches also set flip-flop states. Continuously adjustable frequency range is to 100 kc. Setup includes power supply and eight plug-in modules providing 12 flip-flops, 25 Sheffer Stroke gates, one free running multivibrator, two single shot multivibrators, and nine lamp drivers.—Abacus, Inc., Los Angeles, Calif.

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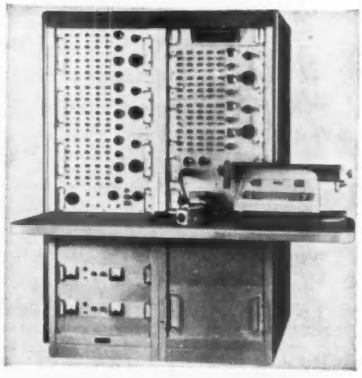
SYSTEMS



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Extremely versatile, this new wide range digital strain gage recording system automatically scans 100 information channels and can be expanded to 200 channels by adding modular units. One-, two-, or four-arm bridges with 60 to 100-ohm gage resistances may be used on all channels. Strain

is read directly in microinches from plus 10,000 to minus 10,000 at a rate of 1 channel per sec.—Bytrex Corp., Newton, Mass.

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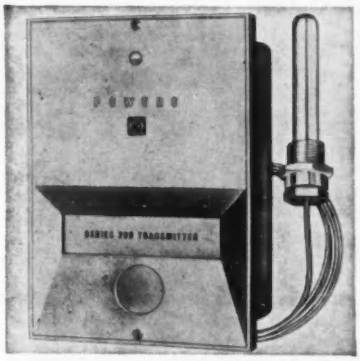

FOR REMOTE TEMPERATURES

The Series 200 transmitter transduces a temperature into a 3- to 15-psi air signal from a remote location. This signal may be sent to a receiver gage which continually indicates temperature or to a receiver-controller. Operating in conjunction with the transmitter, the Series 200 receiver-controller maintains a selected temperature at a remote location.—Powers Regulator Co., Skokie, Ill.

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MEASURES NITROGEN

A new automatic nitrogen analyzer performs the time-tested micro-Dumas method, reading out nitrogen volume in cubic centimeters on a digital counter after a 12- to 15-min cycle. It will measure nitrogen content in an almost unlimited variety of materials, is excellent for numerous determinations presently made by Kjeldahl process. Price is $2,495.—Coleman Instruments, Inc., Maywood, Ill.

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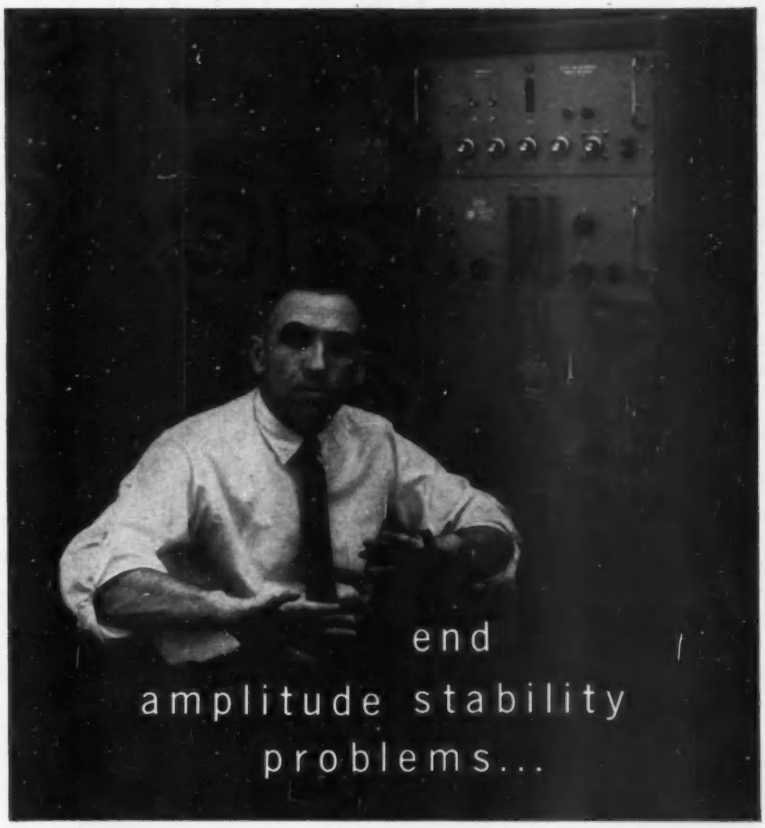

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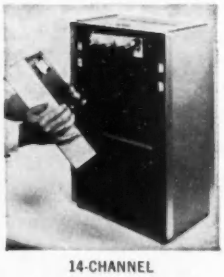

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BULLETINS AND CATALOGS

(400) COMPUTER APPLICATIONS. Bendix Computer Div. Report 10, 4 pp. Illustrated application report entitled "Inventory Control Program" tells how the Bendix G-15 Computer helped solve a complex marketing-inventory problem in a Philadelphia knitting mill.

(401) PRECISION PRESSURE SYSTEM. Consolidated Electrodynamics Corp. Bulletin 1547, 4 pp. Provides a full description of CEC's Electromanometer system, which consists of a precision pressure transducer and a servoamplifier. Bulletin also illustrates the optional readout methods for indicating, recording, and control applications. Specifications are given for both a standard and also for a high speed model.

(402) RUGGED SOLENOIDS. General Electric Co. Bulletin GEA-6215B, 12 pp. Discusses a complete line of industrial strongbox solenoids, including both ac and dc forms. Also contains some useful information on how to select the proper solenoid for a particular job and what to specify when ordering.

(403) NEW SPECTROPHOTOMETER. The Perkin-Elmer Corp. Brochure, 5 pp. Describes the Model 137-G grating "Infracord" IR spectrophotometer, a new low-cost instrument which permits for the first time high resolution runs in the significant near-infrared wavelength region between 0.93μ and 7.65μ. Covers operation and application of the instrument and also includes illustrations of representative spectra.

(404) THERMOCOUPLE ASSEMBLIES. Industrial Div., Minneapolis-Honeywell Regulator Co. Catalog G100-1, 40 pp. Contains over 100 detailed descriptions of complete thermocouple assemblies. Information includes specifications, photos, dimension tables, prices, and ordering information.

(405) ENCODER SYSTEM. Datex Corp. Bulletin 318, 4 pp. Describes how the Datex linear encoder system provides automatic measurement and recording operations in the plant of a Los Angeles metal tube company. Photographs and block diagrams illustrate the major system units and show the techniques that are used for improving accuracy of the basic system.

(406) TAPE INSTRUMENTATION. Consolidated Electrodynamics Corp. Bulletin 1576, 14 pp. Updates information on CEC's new Type 5-752A Magnetic Tape Recorder/Reproducer, a unit which will record and play back five different modes: analog, FM, PDM, CM, or digital.

(407) POWER STEERING SYSTEMS. Vickers, Inc. Bulletin M5110, 18 pp. Covers a new and complete line of production-built power steering components that can be combined to suit virtually any steering axial load requirement. Functionally colored brochure contains component selection tables, performance curves, basic instrumentation diagrams, and typical hydraulic circuit drawings.

(408) CONVERSION FACTORS. Automatic Electric Co. Circular 1956, 21 pp. Pocket sized booklet contains over 800 conversion factors for use in converting fundamental electric and magnetic

units. All units are listed alphabetically and are cross referenced to permit conversion to smaller or larger units.

(409) SILICONES AND THEIR USES. Dow Corning Corp. Bulletin 1-115, 16 pp. Represents an up-to-the-minute summary of the forms, properties, and applications of Dow's various silicone products. Illustrated with photos, tables, and graphs, the bulletin features a contents page which alphabetically lists applications.

(410) GAS CHROMATOGRAPHS. Beckman Process Div. Bulletin GC-4018. Provides complete details and specifications on the structure, performance, operating features, and applications of the Beckman 120-A industrial gas chromatographs. Also included are instrumentation and production photographs, flow diagrams, chromatograms, and dimensional drawings.

(411) BELLOWS DESIGN GUIDE. Breeze Corp. Design guide 77BBP, 16 pp. Presents the story of welded diaphragm bellows, from their basic physics through typical applications. Includes drawings and specifications of the bellows as well as specific illustrations of the different types of welded diaphragm bellows: flexible, expansion, and pressure types.

(412) HIDDEN WATER COSTS. Leslie Co. Bulletin 553-A, 4 pp. Points out ways that proper valve selection and application can reduce "hidden" costs connected with the use of water in industry and focuses attention on the pitfalls in allowing water pressures to go unregulated or poorly regulated. The publication also describes the operation of Leslie's pressure reducing valves and provides complete information on proper sizing procedures.

(413) DIGITAL INSTRUMENTS. Non-Linear Systems, Inc. Short form catalog, 6 pp. Specifications, design features, and applications are presented for a variety of digital voltmeters, ratiometers, ohmeters, voltage and resistance comparators, and associated measuring equipment. Another section illustrates the wide range of accessories that are available for use with these digital instruments.

(414) POWER SUPPLY DATA. Mid-Eastern Electronics, Inc. Bulletin, 4 pp. Describes the company's ST Series of transistorized power supplies. The information given includes complete specifications, mounting dimensions, special features, and prices for 19 off-the-shelf units.

(415) LINEAR FLOW TRANSMITTERS. Bailey Meter Co. Product specification P22-1, 4 pp. Describes Bailey's line of force balance pneumatic transmitters which extract the square root function and produce signals which vary linearly with rate of flow. Selection table lists pressure ranges, service pressures, materials, and weights.

(416) "SOLID STATE CONVERSIONS". Cook Electric Co. Bulletin, 28 pp. Provides concise information on the advantages which solid state conversion have effected in new Cook Electric components systems. These include reduced power requirements, increased life, improved reliability, reduction in size and weight, and improved accuracy.

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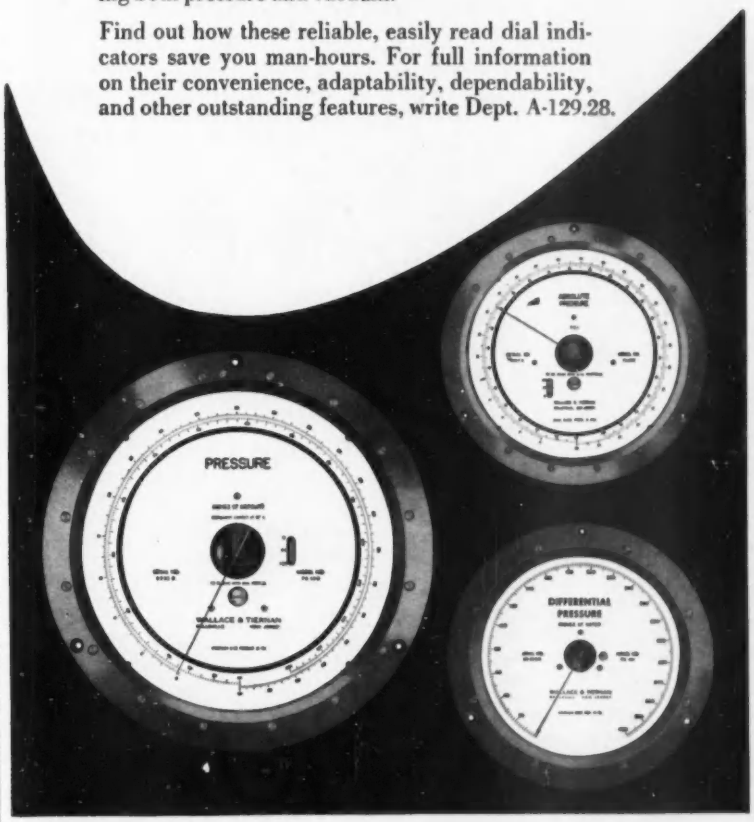

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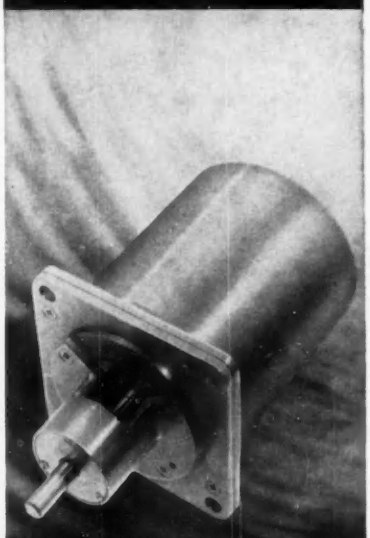
CIRCLE 179 ON READER SERVICE CARD

Electromechanical
Components and Systems
Capability



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Bulletins & Catalogs

(417) CRYSTAL TRANSDUCERS. Kistler Instrument Corp. Data folder 101160, 4 pp. Presents a full line of natural quartz crystal transducers for pressure, force, acceleration, and vibration instruments. In addition to describing the range, sensitivity, and construction of these transducers, the brochure highlights their unique characteristics.

(418) PRESSURE RECORDERS. U. S. Gauge Div., American Machine and Metals, Inc. Catalog 800, 8 pp. Offers specifications and construction details on a line of industrial temperature and pressure recorders. Spiral, Bourdon tube, and bellows-type pressure elements are pictured; materials and performance characteristics are listed. Temperature elements described include a variety of liquid-, vapor-, and gas-filled systems.

(419) REGULATED DC SUPPLIES. Kepco Inc. Catalog B-601, 24 pp. Provides full descriptive data of active standard models in the transistorized, vacuum tube, magnetic, and hybrid design groups of Kepco's wide line of power supplies. Dual index by design group and output voltage range simplifies access to this data.

(420) FANS AND BLOWERS. McLean Engineering Labs., Inc. Short form catalog, 16 pp. Highlights the features and applications of McLean's line of 19-in., rack-mounted, packaged fans and blowers. Covers over 80 models, illustrating housing variations as well as all available accessory items for cooling electronic equipment.

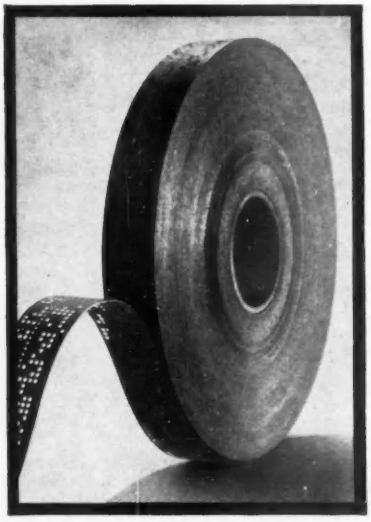
(421) AIRCRAFT INSTRUMENTS. Weston Instruments Div., Daystrom, Inc. Manual, 48 pp. Deals with a complete line of avaition instruments and components. Provides specifications, mounting information, and installation data on meters, transformers, transducers, and a variety of indicating instruments.

(422) PRIMARY ELEMENTS. U. S. Gauge Div., American Machine and Metals, Inc. Catalog 900, 16 pp. Describes a complete line of pressure sensing elements, including both diaphragm and Bourdon tube types. Tables list rated pressure ranges, travel, linearity, maximum pressures, and other special characteristics peculiar to each type.

(423) ADJUSTABLE DAMPING. Fischer & Porter Co. Bulletin 91-251, 6 pp. Discusses the advantages of adjustable damping on differential pressure transmitters for pulsating flow measurements. Graphs illustrate the effects of increasing frequency of the transmitter input signals. Cutaway view of transmitter shows location of the damping adjustment.

(424) TRANSDUCER BULLETIN. Consolidated Electrodynamics Corp. Bulletin 1626, 2 pp. Briefly reviews design features and specifications of the Type 4-327 pressure transducer, a flush-mounted strain gage pickup designed for measuring pressures to 5,000 psi under extreme environmental conditions.

(425) RECORDER SUPPLIES. Brush Instrument Div., Clevite Corp. Folder, 4 pp. Describes chart papers, writing styli,



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New "Peerless" Fibre control tape wears 30 times longer than paper; costs 1/6th that of polyester film!

Need a tough tape that will take machine shop handling? A durable tape for repeat operations? Check the savings in new "Peerless" control tape. It's made of National Vulcanized Fibre, a cellulose plastic—the only tape of its kind!

Compare "Peerless" tape's long, cost-cutting cycle life:

Speed (CODES PER MINUTE)	Paper Tape (CYCLES)	"Peerless" (CYCLES)
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And check "Peerless" tape's amazing properties! It's extra tough, flexible, with high tensile and bending strength. It has high opacity, excellent abrasion resistance and is easily punched. Thicknesses: .0043" and .005"—heavier thicknesses available.

"Peerless" does not stretch in use. Precision-punched holes remain true. In addition, "Peerless" is *plastic-smooth* and impurity-free; friction and wear on punching and feeding equipment are cut to the minimum.

"Peerless" tape is available in any width. It is already proving its superior economies in tape life and cost on major automatic programming equipment in industry, government and business. Colors: Red, Gray, Blue, Black. Investigate now. Write for Free test sample and complete information. Dept. M-6.

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and other supplies available for all models of Brush direct-writing recording equipment. Samples of precision chart papers show typical recording traces in the three basic techniques—ink, electric, and thermal—to demonstrate the uniformity, clarity, and reproducibility.

(426) LEVEL INDICATORS. Fuller Co. Bulletin I-5-C, 8 pp. Deals with the operation and the installation of accurate, automatic material-level indicators designed for use with pulverized, fine, crushed, and granular materials in bins or silos. Discusses a general purpose model, the SG-4, and one special model, the SG-4X, designed for hazardous dust conditions.

(427) SOAKING PIT CONTROLS. Hagan Chemicals & Controls, Inc. Bulletin MS A-177, 12 pp. Covers virtually every component and phase of soaking pit control systems. Subject matter ranges from a description of the soaking pit operation to schematic drawings of several successful control systems installations.

(428) RELAY DATA. Diaphlex Div., Cook Electric Co. Relay manual, 40 pp. Uses photographs, line drawings, and tables in describing some 30 types of relays (with 1,000 variations) for communication, computer, industrial, and military applications.

(429) ELECTRONIC VOLTMETERS. Metronix, Inc., Sub. of Assembly Products, Inc. Data sheet folder. Contains eight separate data sheets describing a variety of panel mounting electronic voltmeters designed for continuous monitoring of critical parameters. Single table shows at a glance the principle specifications of each model.

(430) INSTRUMENT SWITCHES. Cinema Engineering Div. of Aerovox Corp. Catalog, 28 pp. Offers complete information on Cinema's line of precision instrument switches. Sections cover structural styles, standard specifications, modifications and special features, terminal path reference charts, mechanical dimensions, and product descriptions.

(431) MAGNETIC STARTERS. The Clark Controller Co. Publication PL 12-8-160, 8 pp. Covers the Clark Type 'CY' ac magnetic starters in a full range of sizes from 0 to 4. Interesting feature is a well illustrated description of the Clark arc quenching principle, used on the Size 2, 3, and 4 starters to provide greater contact life under heavy current loads and severe arcing conditions.

(432) NEW CERAMIC ELEMENTS. Universal Dynamics Corp. Bulletin, 2 pp. Describes Michelite, an advanced piezoelectric transducer ceramic with job engineered properties. Also lists shapes available, possible applications, and typical physical properties of two different types.

(433) SOLVING A PROBLEM. International Rectifier Corp. Rectifier News—Winter Edition, 8 pp. Part of this issue is a four-page article entitled "Properties of Semiconductor Devices Affecting Voltage Division", in which voltage distribution and various equalization techniques are discussed and analyzed. Also recommends solutions to specific problems.

SORENSEN power rides the weather satellite!
The new weather satellite, TIROS, is one of the most remarkable space vehicles yet to take to the skies. For TIROS carries a complete TV transmitting system into space.
Built by RCA for the National Aeronautics and Space Administration, under technical direction of the U. S. Army Signal Corps, its mission is to televise cloud formations and transmit the pictures back to earth to aid weather forecasters.
Among the advanced electronic equipment in TIROS is a Sorensen dc-to-dc converter that transforms the output of the satellite's solar cells to voltages necessary for the satellite's complex electronic gear. Of course, this converter is both miniaturized and transistorized (weighs only 20 oz.) and its reliability is vital to success of the project.
MORE THAN 130 MODELS
Read about the more than 130 different models of dc-to-dc converters offered by Sorensen in our new 32-page catalog . . . plus a complete line of highly regulated d-c supplies, a-c line-voltage regulators, high voltage supplies to 600,000 volts, frequency changers . . . plus valuable reference data. Write for your copy to Sorensen & Company, Richards Avenue, South Norwalk, Conn.
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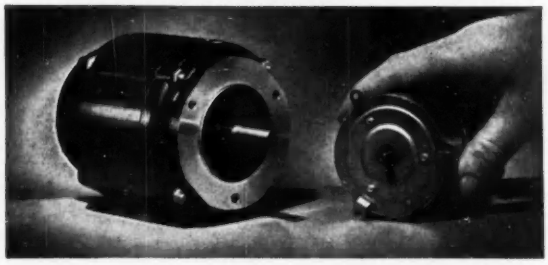
GEARLESS, HIGH-TORQUE, REVERSIBLE

75-RPM and 100-RPM SYNCHRONOUS MOTORS



These amazing gearless motors develop up to 75 oz.-in. torque, feature instantaneous acceleration to synchronous speed within ½ cycle, and have extremely high torque for synchronous motors of this size. Can be reversed instantly. These motors—with lubricated-for-life bearings—withstand continuous duty or stalling with only 40C rise.

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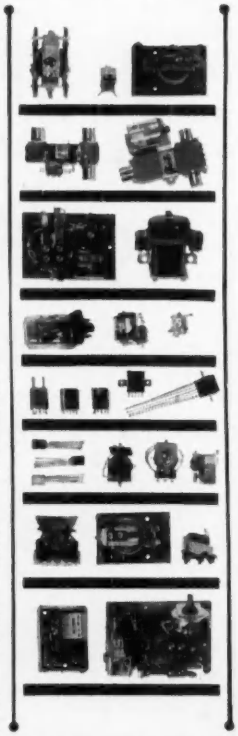

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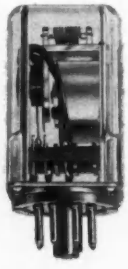
A COMPLETE LINE OF GENERAL PURPOSE (GH) RELAYS ARE AVAILABLE FROM STOCK

These new Advance GH midget relays are engineered for high efficiency and low cost. A tremendous variety of applications permits countless uses. The small size of these midgets allows their installation in equipment where space is a problem. GH relays are available in three open Series—GHA (5 ampere rating), GHB (10 ampere rating), GHS (5 ampere plate circuit type). Also in three dustite plastic enclosure Series—GHP (5 ampere rating), GHH (10 ampere rating), GHE (5 ampere plate circuit type). Enclosures are supplied with 8-pin octal for 1C and 2C, 11-pin for 3C.



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182 CIRCLE 182 ON READER SERVICE CARD

WHAT'S NEW

(Continued from page 45)

board and stockholders approval). Last year's combined sales of the two companies were $148.8 million and combined backlogs, $133 million. The diversified missile and electronics firm will be headed by Robert McCulloch (Temco president) as chairman and chief officer, James J. Ling (L-A president) as vice-chairman and chairman of executive committee, Clyde Skeen (new—see CtE, April '60, p. 204-Temco v-p) as president, and Lee D. Webster (L-A executive v-p) as executive vice-president.

Bendix Aviation Corp. (Detroit) is now sole U. S. distributor and service rep for the machine tool numerical control systems of Ferranti Ltd. of Edinburgh, Great Britain. The system uses the moire fringe technique, new to the U. S. for analog devices.

Kearfott Div. of General Precision, Inc., Little Falls, N. J., has formed a Kearfott Semiconductor Corp. in W. Newton, Mass. Move fits in with corporation's plans for expansion into more electronics work. MIL-type switching transistors will be first products in about six months.

Litton Industries has acquired Servomechanisms (Canada) Ltd. in Toronto. The former subsidiary of Servomechanisms, Inc. was acquired for cash by the Beverly Hills firm.

Clevite Corp. (Cleveland) has purchased Shockley Transistor Corp., of Palo Alto, Calif., from its owner, Beckman Instruments, Inc. The organization is headed by Dr. William Shockley, co-winner of the 1956 Nobel Physics Prize for development of the transistor. Clevite's present Transistor Div. is planning expansion at its Waltham, Mass., headquarters.

Rheem Manufacturing Co., New York City, now has a subsidiary, Rhebo Corp., in Montainview, Calif., to design and build automatic machines for electronics (say, automated transistor manufacture) and other industries.

RCA has formed an Electronic Recording Products Dept. in Camden, N. J., to produce magnetic tape recording devices for data processing, telemetering, and broadcasting.

Vega Electronics Corp. is a new firm in Cupertino, Calif., formed by eight former employees of Ampex Corp. to work in magnetic recording.

Common Market Gathers Steam South of the Border

MEXICO CITY—

After an organization meeting in Montivideo, Uruguay, seven Latin American countries are now studying an agreement to set up a free zone trading area and eventually to form a common market for all Latin America. The tiny nations of Central America are also negotiating a pact; they're expected to join their big brothers as a single unit after they work out their own differences.

Some observers don't give the trade group plan much hope of success in Latin America. They claim traditional nationalistic tendencies—and political instabilities—may upset the well laid plans.

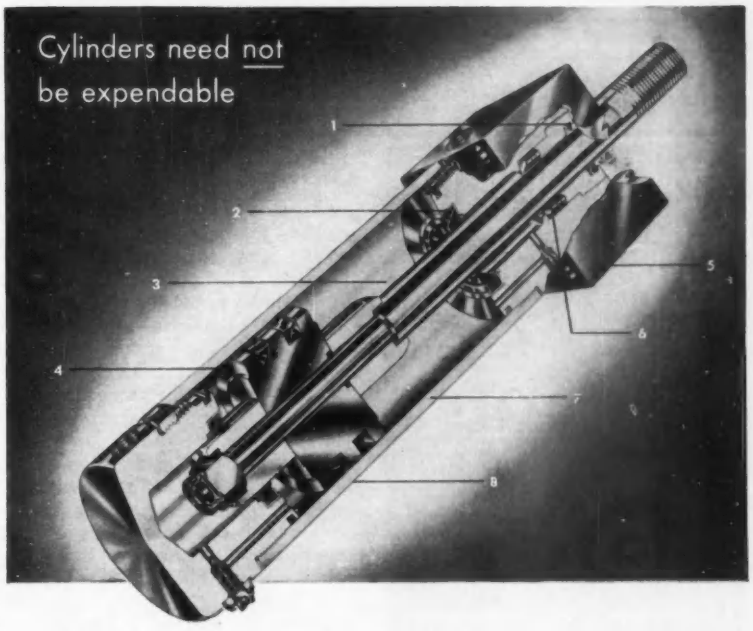
But boosters of the tie-ups are most optimistic, and out of the pact may come a big boost for instrument and controls exports to Latin America. So far, Mexico, Argentina, Brazil, Chile, Paraguay, Peru, and Uruguay have signed the agreement. Bolivia attended the Montivideo meeting but didn't sign. It is expected to join the group before the end of next year—along with Colombia, Ecuador, Venezuela, and the Central American bloc.

Next step is ratification by the member countries' congresses. The Argentina and Uruguan assemblies met last month, Mexico's meets in September. Complete ratification is expected by this fall.

• **What it means**—Each country has agreed, in principal, to work into a plan whereby import duties on member countries' goods are reduced 8 percent a year for a period of 12 years. Duties will remain for outside countries. Later on duties on special items from abroad (i.e., outside the common market) will fit a single tariff list for all the member nations.

Here's the schedule the countries have set up for putting the plan into operation: This month each country will make up and send a list of the items they want to export; by October the countries, having studied each other's export lists, will reply with acceptance or refusal on the various items. The following month all countries will meet to negotiate a single definite list for export-imports to fit into the 8 percent yearly duty reduction plan.

• **Everything's included**—This schedule points up the differences between the Latin American trade bloc and the now well established trade groups in Europe. The European Common Market nations will completely eliminate all tariffs between themselves during the next 15 years. The formula worked out for doing this is a



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You too—can reduce replacement expenditures—lower maintenance costs with the T-J Spacemaker cylinder line. Designed and engineered for ruggedness, and accuracy of operation, the Spacemaker assures longer, uninterrupted operation.

The T-J Spacemaker eliminates tie-rods, gives greater strength, saves space . . . and reduces costs in all push-pull operations. Immediate delivery in a complete range of styles and capacities . . . air or oil. Write for Bulletin SM 155-4, today. The Tomkins-Johnson Company, Jackson, Michigan.

WITH EXTRAS . . . AT NO EXTRA COST

1. METAL PISTON ROD SCRAPER—protects rod packing, cylinder bore and rod surface by removing all foreign particles.
2. NEW "SUPER" CUSHION for air or METALLIC SELF-ALIGNING MASTER CUSHION for oil.
3. HARD CHROME PLATED CYLINDER BORES AND PISTON RODS for greater protection and reduced wear.
4. ONE PIECE PISTON assures better alignment, longer bearing and packing life.
5. FORGED SOLID STEEL HEADS throughout entire line.
6. PILOTED PACKING GLAND with extra long bearing for additional strength and support to piston rod.
7. NO TIE-RODS TO STRETCH—gives you 360° port rotation . . . less space used . . . full strength.
8. STREAMLINED DESIGN . . . operating pressures to 200 PSI, air; 1,000 PSI oil, non-shock.

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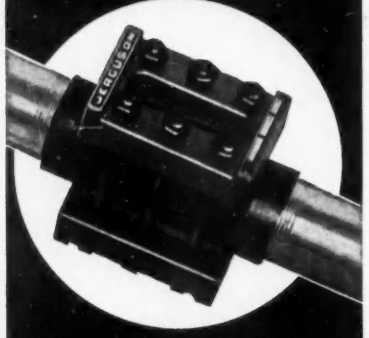
NEW . . .
Jerguson Sight Flow Indicators



easily and inexpensively installed to show movement of liquid in pipe lines

Here is a new line of Sight Flow Indicators . . . easily and inexpensively installed in any new or existing pipe line ½" to 2" N.P.T.

The special design of these new indicators results in a turbulence in the flow of liquid, making it easily visible. Several types of indicating vanes, installed within the chamber, may also be furnished, according to variable conditions of rate of flow and viscosity of liquid. For indication of minute flows, small Sight Flow Indicators with a rotating vertical rising ball are available.

Jerguson Sight Flow Indicators are soundly designed, carefully made, and are backed up by a company with over 40 years experience in the field. Available in Transparent and Reflex types, in a wide variety of materials and linings, and with Wedge Type Illuminators, Haveg Chambers, Non-Frosting Glasses, or other special construction.

If you have a problem of viewing the flow of liquid in a pipe line, it will pay you to investigate the new Jerguson Sight Flow Indicators today. Send us your requirements or write for Data Unit.

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Gages and Valves for the Observation of Liquids and Levels

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WHAT'S NEW

little more complicated than the straight 8 percent progressive method of the Latin Americans, but most important, all goods are included in the European agreement.

The common import duties for goods from outside the Inner Six countries will be the arithmetic mean of the duties in effect on Jan. 1, 1957. A timetable has also been set up to introduce this measure. The agreements between the Outer Seven countries, though not the same as the Six, are similarly much stronger than the LA pact.

The senior European agreement entails more than just economic wall breaking and building. In the future are planned such innovations as labor interchanges, pooling of resources, and a common nuclear power plant.

Of course, the Latin American countries are not yet industrially developed enough to want—or need—such far-reaching plans. Leading industrialists are enough pleased with the way the agreement is working out to be greatly excited about prospects.

• **The outlook for the U. S.**—What does the trade pact hold for U. S. manufacturers selling to Latin America? According to Placido Gardia Reynosa, Mexico's common market expert, it will cause a gradual change in the type of U. S. exports to LA countries and a big dollarwise increase in general.

It will mean the shutting off of consumer goods and light capital goods in exchange for a new influx of heavy industrial products. As the area bands together to lift itself economically, it will want more heavy machinery to set up its own industries. This would not, of course, be an endless stream. If the market were successful, and Latin American did gain in economic and industrial stature, the countries would soon be able to supply most of their own expansion.

But during the initial building stage, U. S. instrument and control makers would have a blossoming market for their wares, for it's axiomatic that new industry needs control goods to get started.

• **To build or not**—As far as building plants in LA to get in on this market, feelings are mixed. Most heads of companies already doing business in Mexico feel that you must first set up shop in any given country on that country's own market possibilities, with the idea of expanding later to export into the common market.

There hasn't been the rush of companies moving in as there was—and is

Now 2 to 3 week delivery on popular BUORD* items...

and in production quantities!

Mark 7 Mod 0 . . . . . Size 15 Servo Motor
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The addition of our second factory means delivery in six to twelve weeks on many other G-M Servo Motors and Motor Generators as well; sizes 8 to 18, including other BuOrd items.

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—in the European case. But there is a steady stream of European and U. S. firms setting up their plants as the place begins to wake up. These outfits will naturally have the jump in selling their products in the common market.

—Peter Weaver
McGraw-Hill World News

Survey Confirms Good Outlook For Business' Spending

Instrument and control makers who cheered last autumn's McGraw-Hill survey of business' spending plans—it showed a 10 percent increase over 1959 (CtE, Dec. '59, p. 45)—and glowed at the report in mid-March from the Dept. of Commerce and the Securities and Exchange Commission that indicated a 14 percent rise will no doubt have to cast about for new adjectives to describe their prospects based on the most recent McGraw-Hill survey.

The report issued by the publishing company's Dept. of Economics shows business plans to spend a big 16 percent more on new plants and equipment than it did last year. All business firms should spend $37.9 billion this year, and what's more, preliminary plans for 1961-63 show healthy advances over 1959's total, though not so great as for this year. It should be noted, however, that businessmen generally underestimate their capital expenditures for periods longer than one year ahead, so these figures will probably pick up later on.

• **To meet the demand**—Instrument companies themselves plan heavy capital expansions—well over the percentage increase average of all business but equal to the average for all manufacturing companies. This group of manufacturers has reported plans that equal a 26 percent gain over 1959. The electrical manufacturing group of companies, which would also include companies in the control field, has plans calling for a sharp increase to $763 million—47 percent more than last year.

Interesting, too, is how companies plan to spend their money. In the manufacturing field 65 percent of capital spending dollars in 1960 will be spent on replacement and modernization rather than expansion. Last year the proportion was almost the same, but with spending up, $3 billion more will be spent for modernization this year. Significant changes in individual manufacturing classifications include the nonferrous metals industry which

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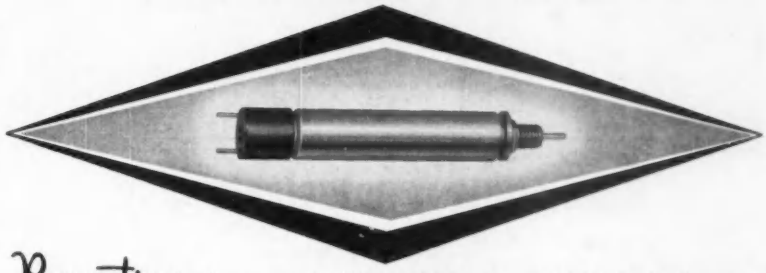

Presenting the new GUARDIAN No. 32 D.C. Solenoid

Long—slim—plenty of power within! Instantaneous thrust with lifts up to 8 ounces intermittent, or 6 ounces continuous duty. Tested to 20 million operations in business machines, computers, data processing, and instrumentation applications where unerring, long life operation in minimum space is imperative. We invite you to test this Guardian No. 32 Solenoid. Arrange for delivery of a production sample.

SPECIFICATIONS

Size: ½" max. diameter—3⅛" long.
Stroke: Up to 5/16" push or pull types.
Lift: Up to 8 oz., intermittent duty; 6 oz., continuous duty.
Duty: Intermittent or Continuous.
Voltages: 6 to 110 volts D.C.
Power: 3 watts continuous duty; 6 watts intermittent duty.
Terminals: Plug-in or lead type
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Mounting: 4-28 Threaded bushing.
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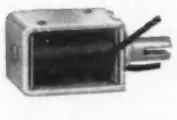
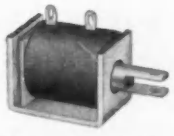


No. 22 D.C.
Size only ¾" x ¾" x 1⅛".
Stroke 1/32" to 5/16".
Lifts up to 24 oz.
Inter. or cont. duty.



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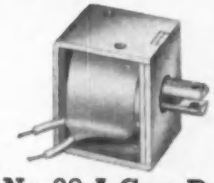
Size 1¼" x 1" x ⅞".
Stroke 1/16" to 5/8".
Lifts over 19 oz.
Inter. or cont. duty.



No. 28 A.C. or D.C.
Size only 1⅛" x 1" x 1 3/16".
Stroke 1/16" to ½".
Lifts over 41 oz.
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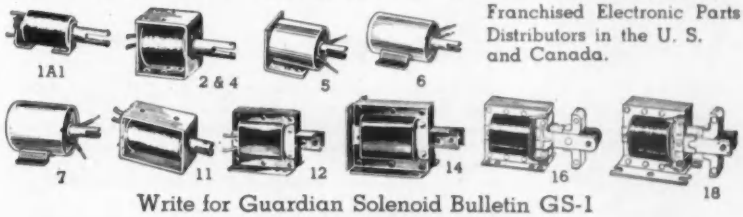
LARGE SELECTIONS of Guardian Solenoids are carried in stock by Franchised Electronic Parts Distributors in the U. S. and Canada.



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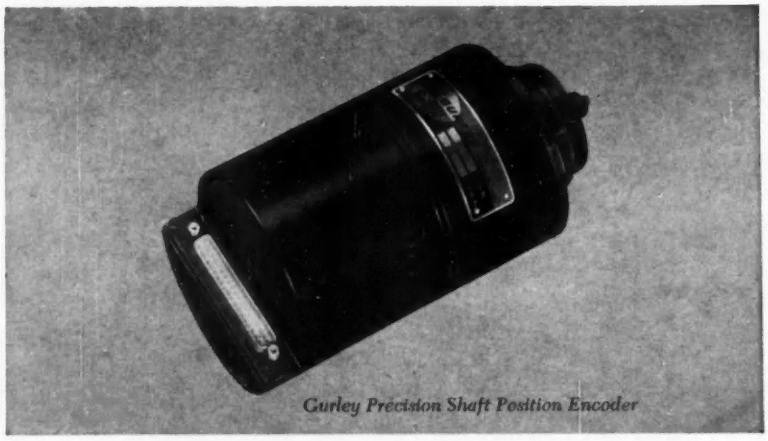

Gurley Precision Shaft Position Encoder

Read Angles Photoelectrically

▶ No friction ▶ High accuracy
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Gurley Precision Shaft Position Encoder is only 3½" in diameter...reads 8192 angular positions per revolution...accurate to 2½ minutes of arc...contains amplifiers to give 3 or 10 volt output.

▶ Write for illustrated brochure.

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MINIATURE MAGNETIC COUNTER WITH SINGLE STROKE RESET JOINS THE FAMOUS *ABRAMS* LINE

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- ▲ **FAST RESET** – Single stroke lever
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- ▲ **SMALL SIZE** – 15/16" x 1¼" x 2"
- ▲ **ACCURATE!** – No loss of count
- ▲ **LONG LIFE** – Over 3 million counts
- ▲ **LOW POWER** requirement – 8.4 watts
- ▲ **RUGGEDIZED** – For extreme environments of vibration, shock, temperature

Available from stock with external case molded in "Cycolac" for rugged use. Case is designed to facilitate nesting or stacking. Four figure, additive counter, Model CZ-1, direct current models for 6, 12, 24 and 110 VDC. Please specify DC voltage when ordering. Use for hundreds of applications on digital readout, statistical, airborne recording, camera data chambers, etc., where size speed and accuracy are required.

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WHAT'S NEW

last year spent 47 percent on replacement and modernization and this year will switch to 67 percent.

The paper and pulp companies will up their expansion budget from 37 percent of their budget to 49 percent. Even more of petroleum refiners' spending will go for replacement and modernization: up to 91 percent from 82 percent in '59. Textile firms will expand more: up to 30 percent from 16. Only the chemical industry will spend more for expansion than modernization.

• **Something new** – A significant piece of manufacturers' research and development programs (R & D spending is reported up 6 percent from last year's record and due to be up another 12 percent by 1963) will be devoted to new products. Manufacturing companies surveyed estimated that 12 percent of their sales for 1963 would be in products not made in 1959 or products changed enough to be new.

Close to a third of manufacturing companies answered that a significant share of their 1960 capital expenditures would be to make new products. Chemical firms logged the highest showing here; 55 percent of the cooperating firms in this field were allocating significant parts of 1960 dollars for new products.

IMPORTANT MOVES BY KEY PEOPLE

Indiana Standard Names Head of Computer Facility

Hal M. Hart has been selected by Standard Oil Co. (Indiana) to be director of a project to develop new ways to use electronic computers in controlling selected processes for refining petroleum. (See p. 40 for details of SOIND's program.)

Hart has been with Standard since 1940 and has experience in supervising technical service to refineries. A chemical engineer, he's recently been assistant superintendent of technical service at the Whiting refinery.

Kirkham New Chief Engineer For P & W's Machinery

The Pratt & Whitney Co., Inc. of W. Hartford, Conn. has appointed Edward E. Kirkham chief engineer of the machinery engineering department. Kirkham has been a chief development engineer since 1958.

Since joining P & W in 1953 Kirkham has been instrumental in developing the company's numeric-

controlled machine tools and inspection machines.

Kirkham joined another Pratt & Whitney–Aircraft in East Hartford–after graduating as an M.E. from Kansas State College. He's also been employed as an electrical designer at Federal Electric Products Co.

Daystrom Names Overall Company Research Head

Roswell W. Gilbert has the new post of director of corporate research of Daystrom, Inc., Murray Hill, N. J. The move is designed to intensify and expand development work of the company in several areas of electronics. Gilbert has been vice-president of research and development for Daystrom's Industrial Products Group.

Headquarters for the enlarged research group were opened last month in W. Caldwell, N. J. The unit is expected to concentrate on specific areas like electrical measurement, semiconductors, metallurgy, and data and control systems.

Other Important Moves

Donald R. Piatt has joined Universal Controls, Inc. as director of engineering. He comes from Underwood Corp. where he was vice-president of research and engineering.

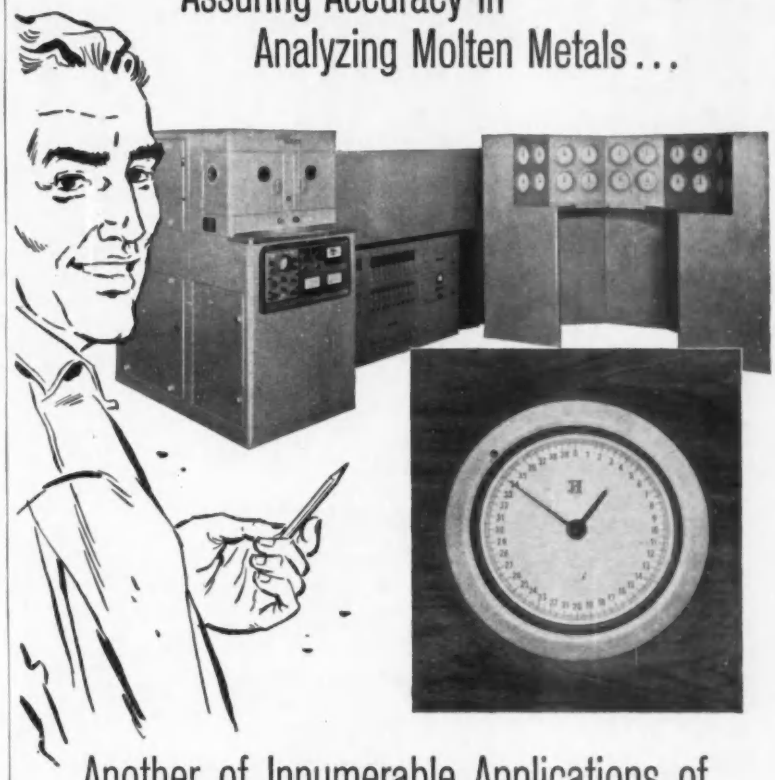
Chester C. Holloway is the new president of Gilman Engineering and Mfg. Co., a subsidiary of Parker Pen Co. in Janesville, Wis. He replaces William C. Cummings who has become vice-president of Eversharp Pen Co., a division of Parker. Gilman produces automatic assembly equipment.

Leo M. Chattler is the newly appointed general manager of Raymond Atchley, Inc., a subsidiary of American Brake Shoe Co., in Los Angeles. Chattler's background covers 20 years in automatic control including positions as manager of electromechanical products in the Vought Electronics Div. and chief of automatic controls for Chance Vought Aircraft, Inc.

Joseph D. Yanak has been promoted to manager of M. W. Kellog Co.'s Brazilian operations. He's president of the New Jersey section of I.S.A.

Charles F. Adams holds the new position of chairman of the board and **Richard E. Krafve** is president of Raytheon Co., Waltham, Mass. Adams has been president of the firm since February 1948. Krafve joined Raytheon last year as a group vice-president from a position as v-p at Ford Motor Co.

Assuring Accuracy in Analyzing Molten Metals...



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What's your special timing requirement? For precise time measurements in specialized electronic instruments, as on this Direct Reading Spectrometer (product of Baird-Atomic, Inc.) where Standard timers are used in the readout to indicate per cent concentration of elements in molten metal? Or for accurate control and test timing—as with many manufacturers in the electronics and missiles fields?

Whatever your needs, STANDARD has the experience and facilities to develop the timer suited to your circumstances. (Accuracies to ± .001 seconds available in standard models.) Write today outlining your requirements.

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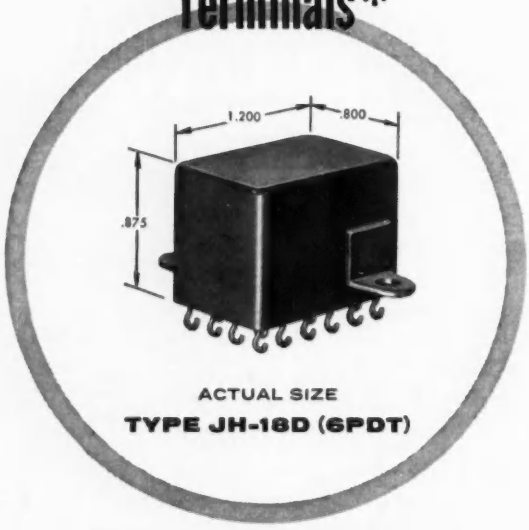

ACTUAL SIZE

TYPE JH-18D (6PDT)

OPERATING CONDITIONS

CONTACT RATING:
2 amperes non-inductive or 1 ampere inductive at 29 volts d-c or 115 volts a-c
Low level contacts are available on request

AMBIENT TEMPERATURE:
— 65°C to + 125°C

VIBRATION:
5-28 cps at 0.5 inch double amplitude
28-2000 cps at a constant 20g

SHOCK:
50g operational

WEIGHT:
1.8 ounces maximum

*Also available with straight pins for printed circuit application

Write for Bulletin JH-18D #25

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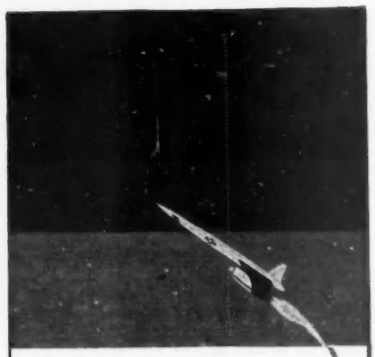

COMPUTER ENGINEER

The Missile Division of North American Aviation has a position in its Flight Simulation Facility for an engineer with background in analog and digital computer circuitry, theory, logic, and a general knowledge of transistor theory. This position involves responsibility for the proper electronic operation and refurbishing procedures associated with analog and digital computers with a completely transistorized analog and digital conversion unit. The position involves the design and/or specifications of new computer components and equipment commensurate with the technological needs of the Division. It will provide association with analog and digital simulation techniques on some of the most advanced missile and space programs in the country. Requires minimum of BSEE and three years applicable or related experience.

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MISSILE DIVISION
North American Aviation, Inc.

ABSTRACTS

Handling requirements

From "The Determination of Lateral Handling Quality Requirements from Airframe-Human Pilot System Studies", by I. L. Ashkenas and D. T. McRuer, Systems Technology, Inc. WADC Technical Report 59-135; ASTIA Document No. AD 212 152. 80 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. Price not stated.

Present day lateral handling quality requirements are based upon experiments with craft having certain dynamic characteristics which differ markedly from those occurring in more modern configurations. This departure from past norms has led, in some instances, to unsatisfactory flying qualities in aircraft which met current specifications. In some cases this type of problem can be predicted or explained by the application of existing pilot dynamic response data to servo analysis studies of airframe-pilot systems. These studies result in specifications upon the magnitudes and/or the relative location of airframe transfer function poles and zeros.

In the present paper this approach is used to derive tentative criteria for certain roll/aileron transfer function quantities. These criteria are examined in the light of existing pilot opinion data, and limited regions of validation are established. For those regions where no data exist, the tentative criteria can provide an interim basis for design and a guide to future testing.

Pilot describing functions and airframe transfer functions are combined within a servo analysis framework to develop a partial theory of lateral handling qualities. Tentative criteria for certain roll/aileron transfer function quantities are derived and compared with existing pilot opinion data to establish limited regions of validity.

Overcoming dead time

From "A Method for the Optimum Control of Systems with Dead Time", by H. Schliessmann. Regelungstechnik, December 1959, pp. 418-421. In German.

The author studies the behavior of a proportional controller with feedback in a control loop having dead time. If the feedback is designed to

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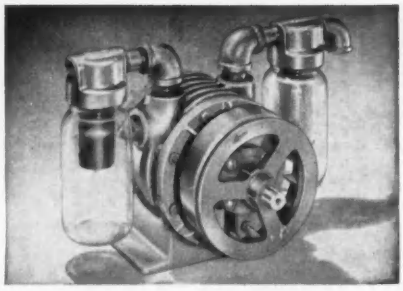

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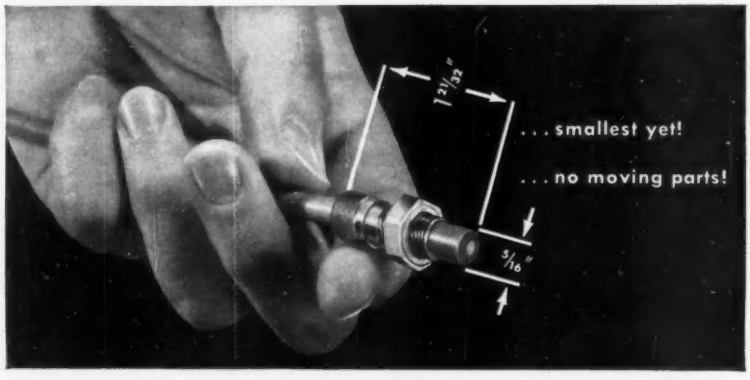

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ABSTRACTS

be an analog of the controlled plant and provided the controller is suitably dimensioned, it should be possible to compensate for a step disturbance occurring at the output end of the controlled plant after no more delay then the dead time, without overshoot. The drawbacks and limitations of the method are discussed.

Compressor control

From "Capacity Control of Reciprocating Compressors", by D. L. Hagler, Linde Co. Paper 25-H60 presented at the Houston Conference of the Instrument Society of America, Feb. 1-4, 1960.

The paper covers compressor capacity control devices and the economical application of these devices depending on the stability and flow requirements of the process. Several electrical-pneumatic control loops for sensing varying process conditions and effecting proper sequencing of compressor loading devices are presented and evaluated from the standpoint of reliability, safety, and economics.

A table compares flow recirculation control and compressor unloading control.

Static power converters

From "Transistorized Power Supplies—A Literature Survey", by F. Allen, Diamond Ordnance Fuze Lab. Available from the Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. as PB 161266, 23 pp., 75 cents.

The survey of technical information on transistor converters shows how to use various electrical converters to best advantage to get high voltage from a low voltage dc power supply. Through the use of charts and schematic diagrams, the report compares the efficiency of transistorized converters, vibrator-transformer converters, and dynamotors. Examples are given of functional circuits using power transistors as controlled switches. The transistor converter, which has no moving parts, was found to be more efficient in many situations than either the rotary converter or the vibrator unit. The report points out that low dissipation loss in transistors accounts for an output of several hundred watts at conversion efficiencies up to as high as 95 percent.

NEW BOOKS

Hydraulics Text

OIL HYDRAULIC POWER AND ITS INDUSTRIAL APPLICATIONS. *Walter Ernst. 2nd edn. 467 pp. Published by McGraw-Hill Book Co., Inc., New York.* $12.50.

The last 10 years have witnessed an unprecedented development and increase in applications of fluid power. This second edition is revised, enlarged by a 100 pages, and incorporates the latest information and techniques aimed at reaching the increased audience engaged in the design, manufacture, and study of hydraulic power.

To those who are familiar with the original edition and lamented its lack of the latest information, the revised text will be a welcome source of new material. Almost all the chapters are reedited and expanded by the addition of new sections. The book contains information on high temperature synthetic hydraulic fluids, their properties, and supply sources. Hydrodynamic effects in rotating fluids, energy losses, noise and vibration, and JIC Standards are also newly treated. Theory and basic equations on hydro static bearings are added. This particular hydraulics area is becoming especially important since air bearings did not come up to expectations due to the difficulties encountered in stability and control.

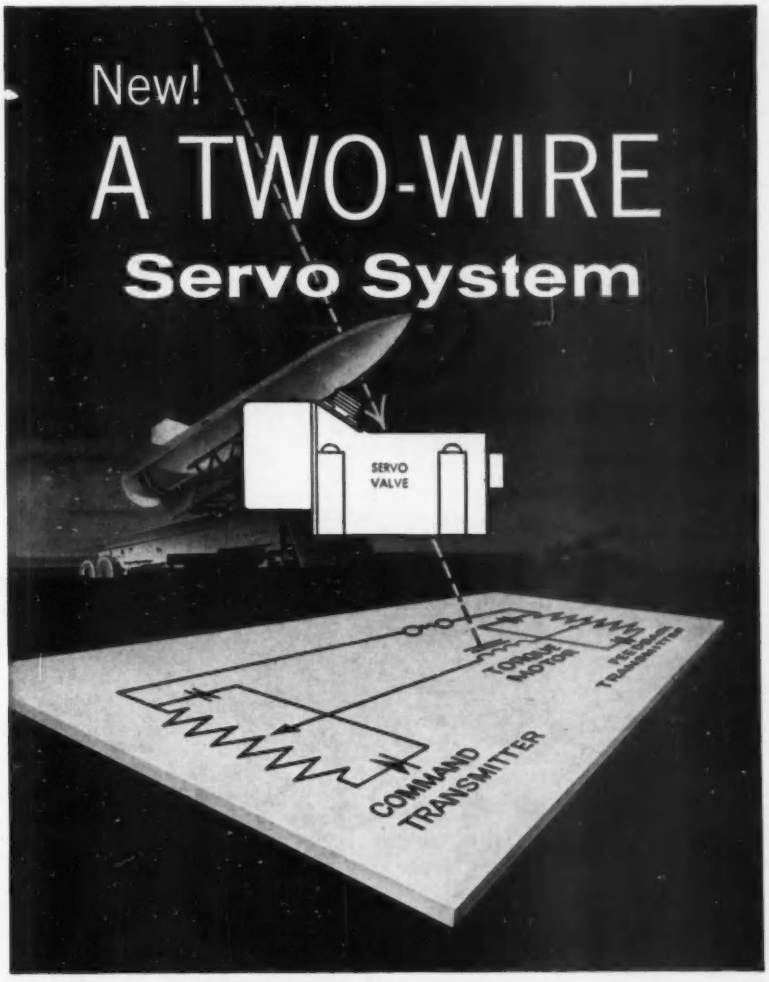
The excellent visual presentation in the book explains clearly the functioning of various valves and hydromechanical controls. Chapter 11 deals with servomechanisms analysis, circuits, and valves. The references given at the end of the chapter are both extensive and useful. While the beginning chapters have detailed fundamentals on hydraulic power, its generation, and control, the final chapters show extensive applications on various machines, presenting drawings of hydraulic circuits and explaining the functioning of their components and how automatic control is achieved.

Mitchell Sabanas
Armour Research Foundation

Medical Engineering

BIOLOGICAL AND MEDICAL ELECTRONICS. *Ralph W. Stacy, Ohio State University. 308 pp. Published by McGraw-Hill Book Co., Inc., New York.* $9.50.

"Present-day medical education does not teach instrumentation adequately," states Prof. Ralph W. Stacy.



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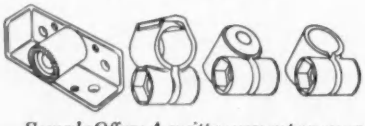

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NEW BOOKS

To close this gap, Prof. Stacy has written a textbook in which the fundamentals and basic facts of electronic techniques in measurement are explained in excellent order and simple, down-to-earth terms. His course in the Biophysics Div. of the Dept. of Physiology of Ohio State University is the basis for the book, which covers his lecture material. Although this volume is intended primarily to supply background information on instrumentation for the medical man, it is also useful to engineering students who intend to specialize in biomechanics, life sciences, or as this reviewer prefers to call the field, medical engineering.

The subject matter covers the theory of measurement, instrumentation, fundamentals of electricity, and vacuum tubes and their application in electronic circuits and in sensing and recording devices. Wiring diagrams of instruments that are used in measurements of nerve action, blood flow, cardiovascular phenomena, and other functions are detailed. The book also includes sections on instrument checking and repair, transistors and their functioning as components in circuitry, and computers as laboratory instruments. Particularly valuable are the footnote references and bibliographies listed at the end of all but two of the 11 chapters.

The text is well recommended for design engineers who are not familiar with measuring instruments as well as for those who either plan to work or are currently working with biologists and doctors on space flight problems. They will learn valuable basic terminology not only in measurement techniques but also a common language which will improve communication between the two professions.

Prof. Stacy is to be commended for this forthright and pioneering book which goes a long way toward educating medically oriented men to apply engineering knowledge for the advancement of the combined sciences.

Mitchell Sabanas
Armour Research Foundation

Component Directory

THE RELAY GUIDE. *Raymond N. Auger. 382 pp. Published by Reinhold Publishing Co., New York 22, N. Y. $10.*

This book contains condensed technical data for each of almost 1000 relays abstracted from the literature of about 200 American manufacturers.

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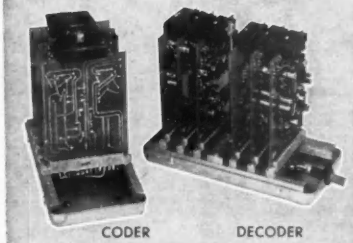

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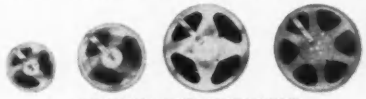

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MEETINGS

JUNE

Instrument Society of America, Sixth annual Instrumental Methods of Analysis Symposium, Montreal, Canada June 1-3

American Society of Mechanical Engineers. Semi-Annual Meeting and Aviation Conference, Statler-Hilton Hotel, Dallas, Tex. June 5-9

Material Handling Institute, New England Show, Commonwealth Armory, Boston, Mass. June 6-8

American Institute of Electrical Engineers, Summer General Meeting, Atlantic City, N. J. June 20-24

Second National Conference on Electronic Standards and Measurements, sponsored by National Bureau of Standards and IRE, National Bureau of Standards Laboratories, Boulder, Colo. June 22-24

Institute of Radio Engineers, Fourth National Convention on Military Electronics, Sheraton-Park Hotel, Washington, D. C. June 27-29

International Federation of Automatic Control, First International Congress on Automatic Control, Moscow, U.S.S.R. June 27-July 6

JULY

Seventh Annual Symposium on Computers and Data Processing, Denver Research Institute of University of Denver, Stanley Hotel, Estes Park, Colo. July 28-29

AUGUST

Fourth National Heat Transfer Conference and Exhibit, sponsored by AIChE and ASME, Statler Hotel, Buffalo, N. Y. Aug. 14-17

Western Electronic Show and Convention (WESCON), Ambassador Hotel and Memorial Sports Arena, Los Angeles, Calif. Aug. 23-26

SEPTEMBER

Joint Automatic Control Conference, sponsored by ASME, AIEE, IRE, ISA, and AIChE, Massachusetts Institute of Technology, Cambridge, Mass. Sept. 7-9

Production Engineering Show, Navy Pier, Chicago, Ill. Sept. 6-16

National Machine Tool Builders Association, Machine Tool Exposition (in connection with Product Engineering Show) International Amphitheatre, Chicago, Ill. Sept. 6-16

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RADARGRAMMETRY

Just Published. Analyzes sources of error found in the real radar display and outlines a unified system design for keeping errors within bounds to meet an overall criteria of system performance. Covers image motion compensation—antenna stabilization—linear apertures for optical systems—theory of radar return—earth's magnetic field—shading on the cathode-ray tube—and much more. **By Daniel Levine, Consultant Engineer. 330 pp., 200 illus., $12.00**

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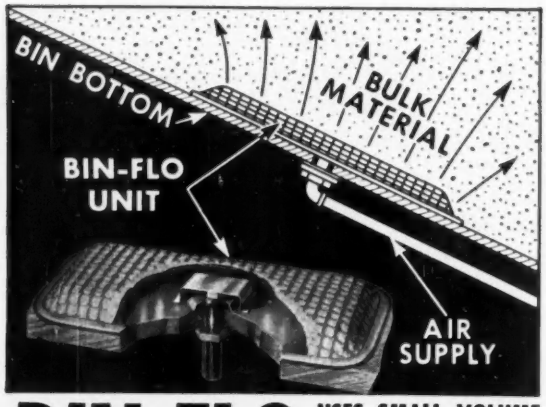

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WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Single copies of any reprint can be obtained at the nominal cost listed below by circling the corresponding numbers on a reader service card, p. 170. Don't send money with card, we will bill you later. For multiple copies write Reader Service Dept. Quantity rates will be quoted on request.

502—Survey of Dynamic Display Techniques, 20 pp. The function of these newly developed techniques is to put up-to-date information in the hands of human operators of control systems when the information changes at a high rate. Both basic approaches and commercial hardware are discussed for cathode ray tube displays, optical system, and miscellaneous devices ranging from TV pickup to matrix cells. 50 cents.

501—Six Transducers for Precision Position Measurement, May 1960, 6 pp. Explains operation and gives practical application hints for six precision position transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

500—Ready Reference Data Files—I, II, III, 76 pp. The feature here is a special rate for those who purchase all of the Data Files published in CONTROL ENGINEERING through April 1960. The 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. $1.35.

499—Ready Reference Data Files—III, 28 pp. Includes the third dozen Data Files published in CONTROL ENGINEERING. Topics range from control of metal properties with eddy currents to electrically signaled valve actuators to stabilization of sampled data systems. 60 cents.

498—Ready Reference Data Files—II, 24 pp. Includes the second dozen data

Continued on page 198

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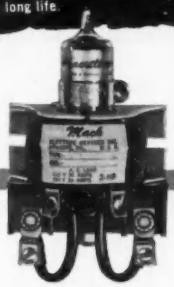

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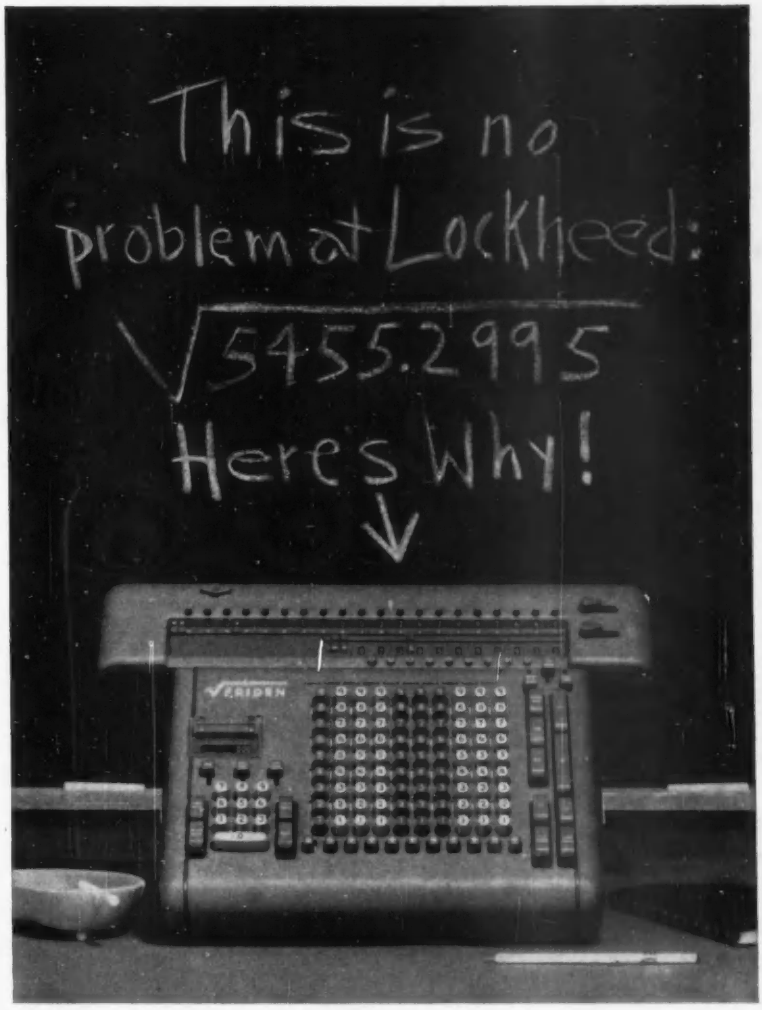

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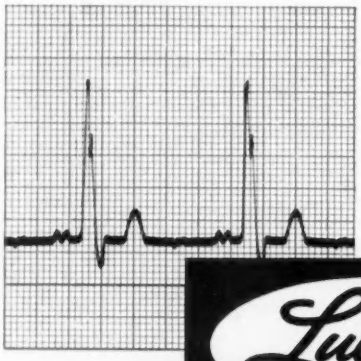

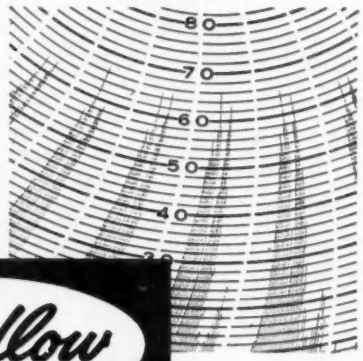

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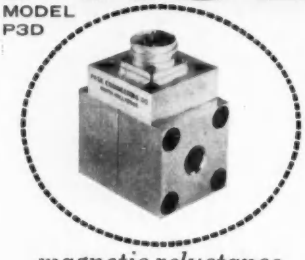

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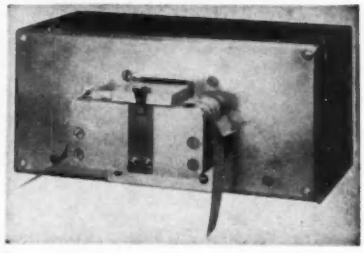

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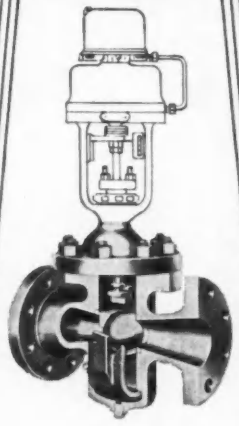

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482—Static Switching Devices—New Tools for Industrial Control, May 1957,

Continued on page 200

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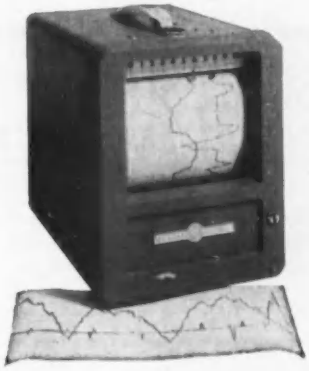

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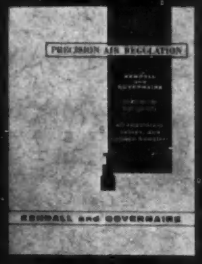

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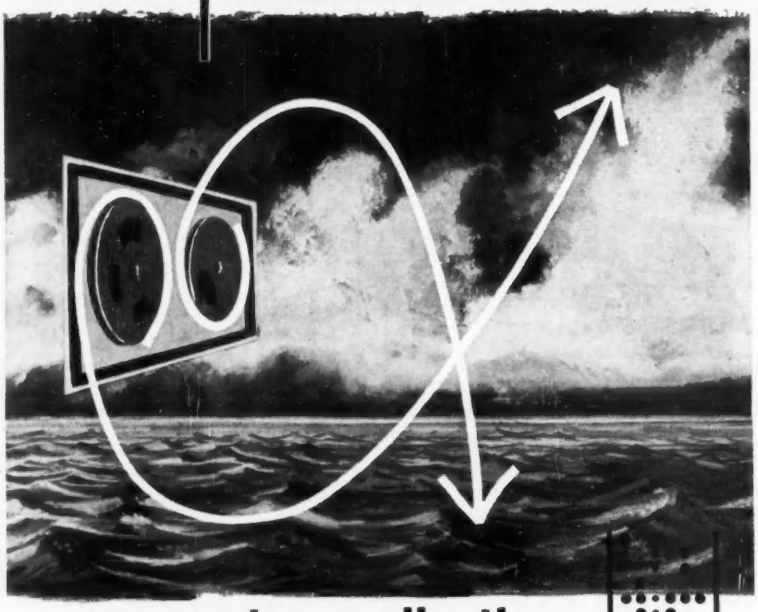

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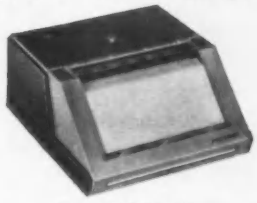

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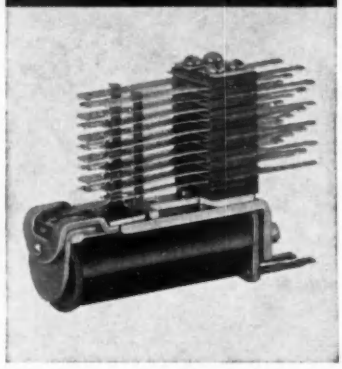

. . . featuring new high-voltage types for test equipment or other high-voltage applications.

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Type B: *a gang-type relay with up to 60 Form "A" spring combinations.*

Type BB: *relay accommodates up to 100 Form "A" springs.*

Type C: *two relays on the same frame. A "must" where space is at a premium.*

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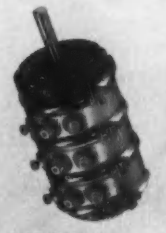
Type MFR — encapsulated contact patented Metlfilm, ultra-reliable, long life potentiometers.

PVR05



PVR09 (ganged)

PVR15

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Type M10T09 — multi-turn (3, 5, 10-turn) highly accurate precision potentiometers.

C10-09 (ganged)

Type C10-09 — 10 turn, may be ganged.

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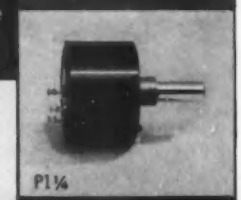

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60 Second Contact Convertibility

NOTICE!

ALLEN-BRADLEY CONTROL RELAYS can thus easily be changed from N.O. to N.C. (or vice versa)

Why not give yourself a real surprise! We refer to the ease with which you can convert the contacts of these Allen-Bradley Bulletin 700 Type BR control relays. Using only a screwdriver, contacts can be changed from normally open to normally closed (or vice versa) in seconds—without removing the relay from its mounting—or its wiring. This "on-the-spot" convertibility certainly suggests an appreciable moneysaving reduction in your relay inventories.

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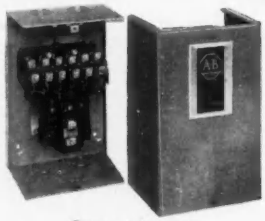
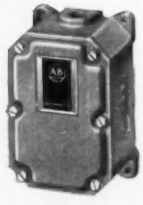
BUT HEAR THIS!

In the event that when "on-the-job" it is discovered that something was either overlooked or added, the standard Bulletin 700 Type BR—either 2, 4, or 6 pole relay—can easily have added to its base, out in the field, either one or two switching poles. It is done as easily as "falling off a log."



General-Purpose
NEMA 1



Explosion-proof
NEMA 7

Waterproof
NEMA 4

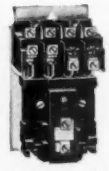
FIVE RELAYS IN ONE

This shows how a Type BR relay can be arranged—in seconds—to do the job of five different relays.

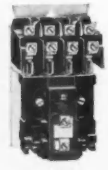
3 N.C.—1 N.O.

3 N.O.—1 N.C.

4 N.C.



2 N.O.—2 N.C.



4 N.O.

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